Appendix A: Design Loads

The following loads were those used in the design of the two-way concrete floor system and the concrete columns. It should be noted though that RAM Concept automatically includes the self-weight of the slab in the design loads.

Roof Loads	
Dead Loads	
10" Slab	125 PSF
Insulation + Roof Board	11 PSF
Misc. Dead	10 PSF
Live Loads	
Roof Live	30 PSF
Mechanical Well	150 PSF

Table A1: Roof Loads

Floor Loads	
Dead Loads	
10" Slab	125 PSF
24"x 30" Beams	500 PLF
24"x 24" Beams	350 PLF
16"x 24" Beams	233 PLF
Misc. Dead	16.5 PSF
Live Loads	
General Collections	150 PSF
Office + Corridors	80 PSF
Reading Rooms	80 PSF
Stairs	100 PSF
Exterior Wall Loads	
Masonry	91.875 PSF
Curtain Wall	30 PSF

Table A2: Floor Loads

Pattern loading:

ACI 318-11 Section 13.7.6.2 states that when the live load accedes ¾ of the dead load pattern live loading must be considered in the design of the slab system. Therefore, pattern loading was used in the design of the floor slabs. Also, RAM Concept fully considers any pattern loading effects while considering loading factors, and envelope results.

Appendix B: Floor Design Options – Conventional Reinf.

Option 1: Flat Slab with Drop Panels (Original)

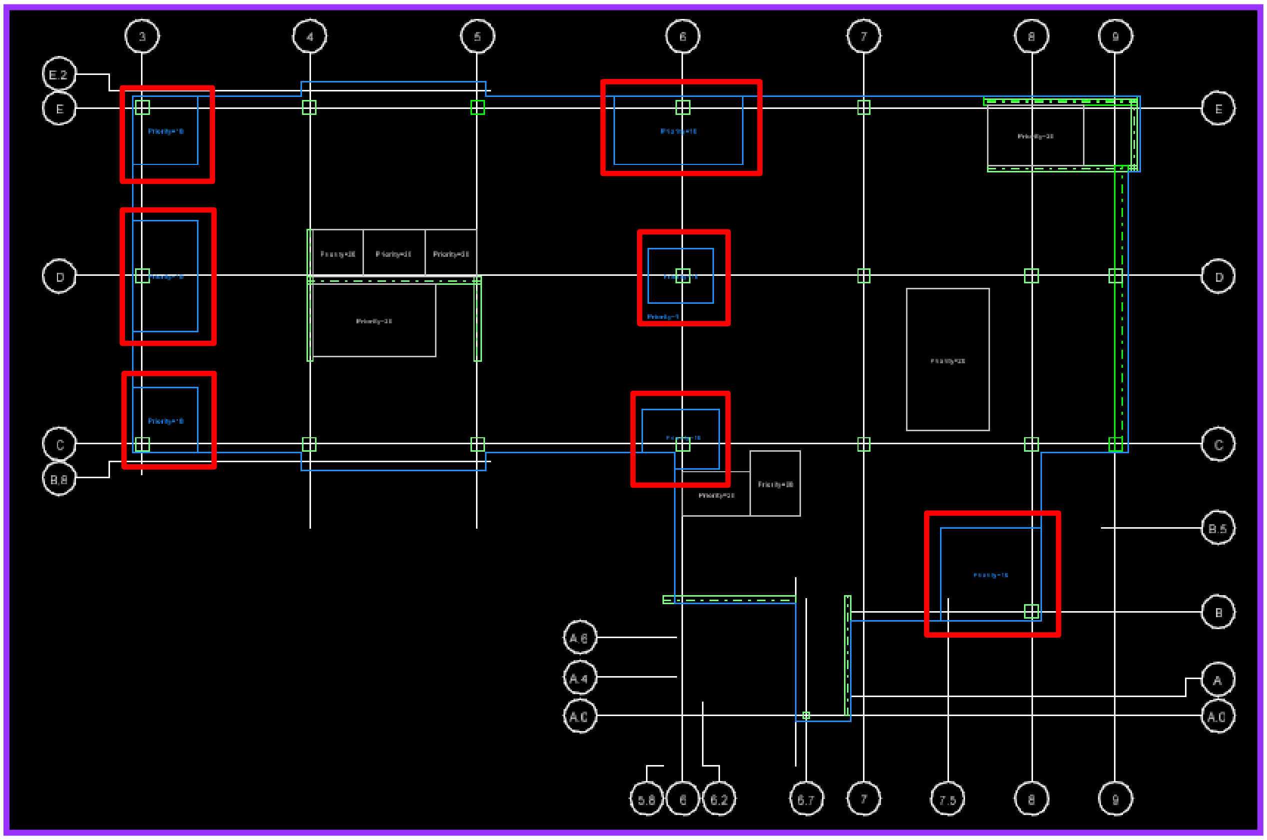


Figure B1: Floor Option 1

Column	-X	+X	-Y	+Y	Thickness (in)	Required Increased Size
3E	1.33	8.44	8.44	1.33	6	Yes
3D	1.33	8.44	8.44	8.44	9	Yes
3C	1.33	8.44	1.33	8.44	9	Yes
6E	10.33	9.11	8.44	1.33	4	Yes
6D	5.17	4.56	4.22	4.22	6	No
6C	6.20	5.47	3.83	5.07	2.5	Yes
8B	13.67	1.33	1.33	12.67	13	Yes

Table B1: Floor Option 1 Drop Panel Sizes

Slab: 10”

→This floor design was unacceptable do to the large drop panel sizes required to resist the punching shear. There was also a large concern that the required deflection limits for the masonry façade would not be met.

Option 2: Flat Slab with Drop Panels and Beams

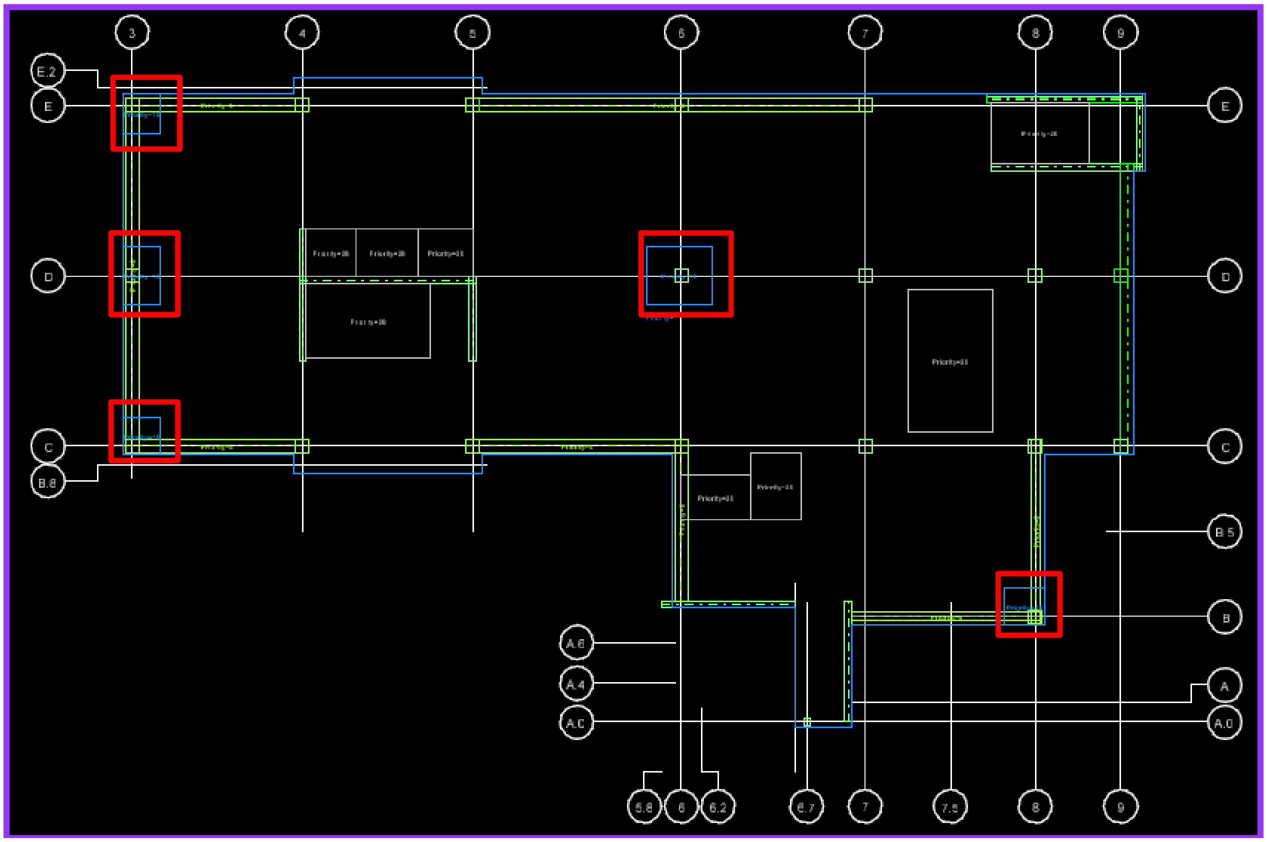


Figure B2: Floor Option 2

Column	-X	+X	-Y	+Y	Thickness	Required Increased Size
3E	1.33	4.22	4.22	1.33	6	No
3D	1.33	4.22	4.22	4.22	9	No
3C	1.33	4.22	1.33	4.22	9	No
6D	5.17	4.56	4.22	4.22	6	No

Table B2: Floor Option 2 Drop Panel Sizes

Slab: 10”
Beam Sizes: 16x24 &24x24

→ This floor design showed improvement in the decreased drop panel sizes, and the edge beams provided increase stiffness to help limit deflections. All drop panels were sufficient based on the L/6 requirement, but all required increased thickness due to punching shear failures at the perimeter of the columns.

Option 3: Flat Slab with Shear Stud Rails

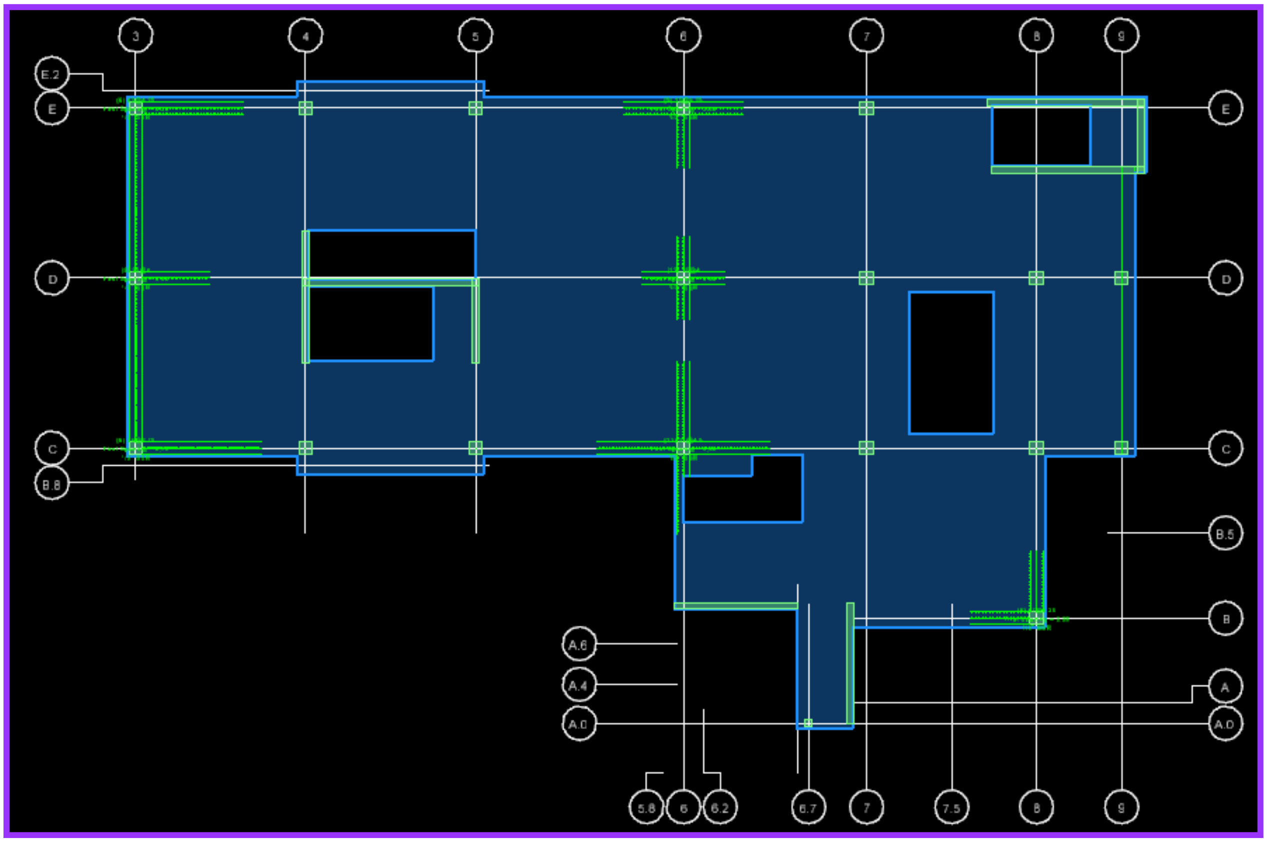


Figure B3: Floor Option 3

Slab: 10”
Studs: ½” Diameter

→ This floor design was primarily created in the interest of determining the required number of shear studrails if no beams or drop panels were to be used. It can be seen that the majority of the shear studrails would be unnecessary if edge beams were added, which would be needed anyway in order to limit deflections.

Option 4: Flat Slab with Shear Stud Rails and Beams

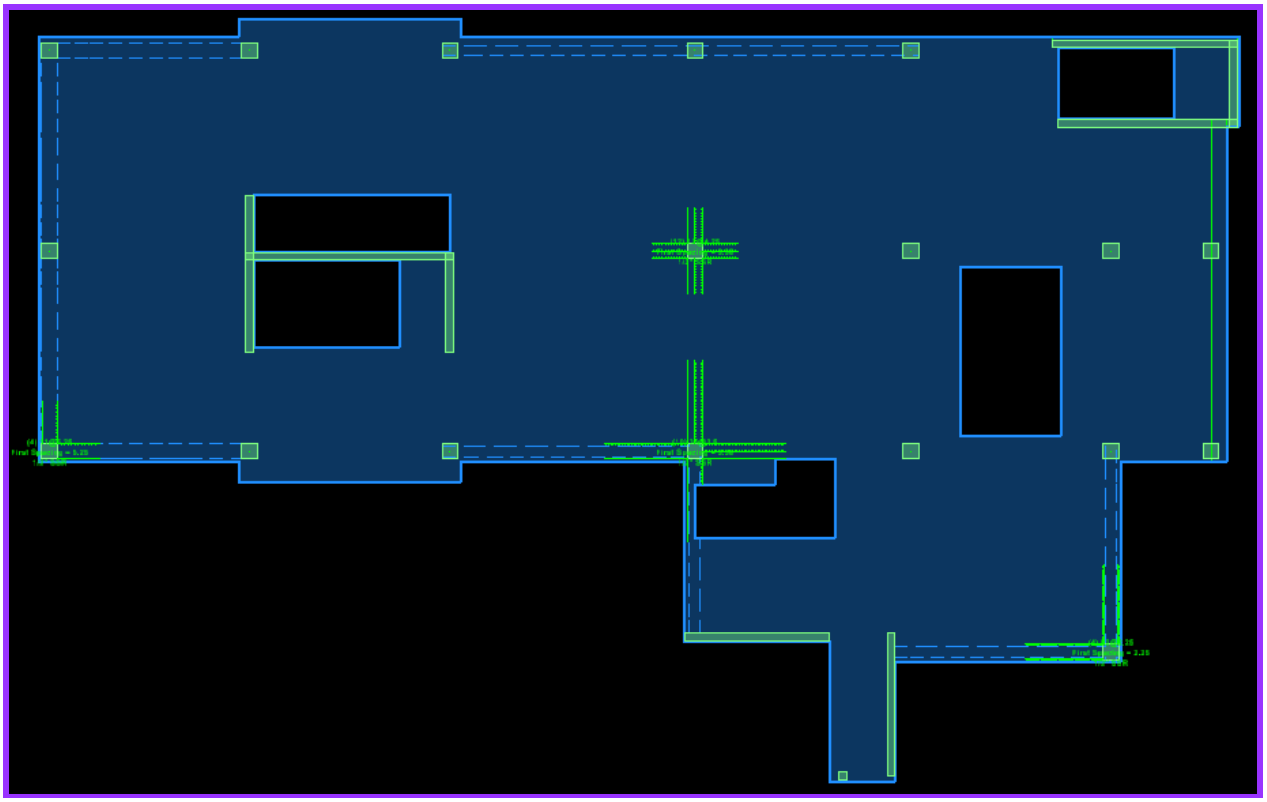


Figure B4: Floor Option 4

Slab: 10”
Studs: ½” Diameter
Beam Sizes: 16x24 & 24x24

→ This floor design showed improvement in the decreased number of shear studrails, and the edge beams provided increased stiffness to help limit deflections. It was determined that studrails near beams were minimal and an increased beams size would eliminate the need for these studrails.

Option 5: Flat Slab with Shear Stud Rails and Larger Beams

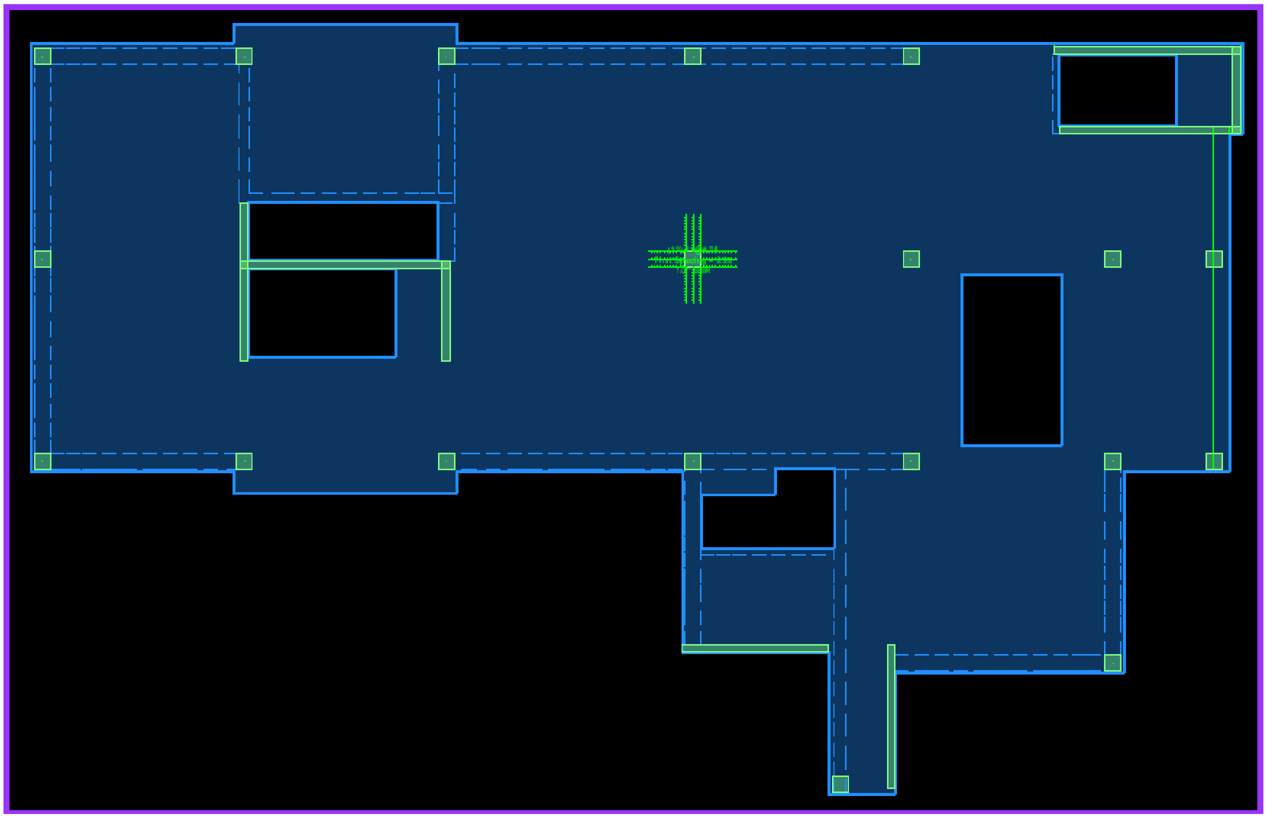


Figure B5: Floor Option 5

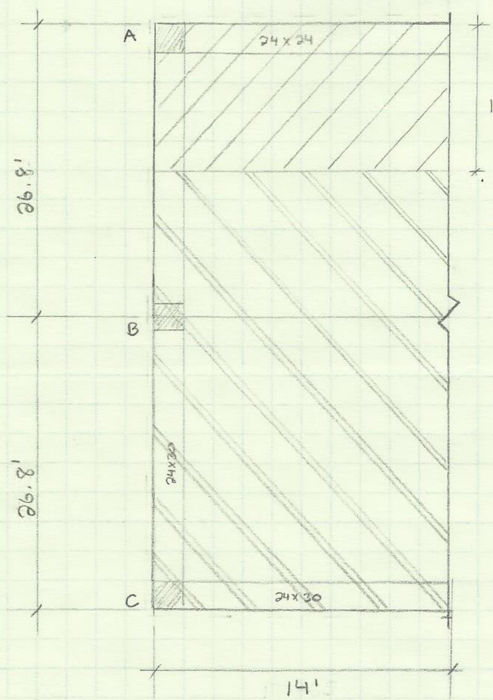
Slab: 10”
Studs: ½” Diameter
Beam Sizes: 24x30 & 24x24

→ This floor design was determine to be the best choice due to the decreased number of shear stud rails, and the edge beams provided increase stiffness to help limit deflections.

Appendix C: Verifying Model

Appendix C.1: EFM vs. FEM

Column Line 3



f'c = 4000psi
height = 16 ft
Slab = 10 in

80psf Live Load (reducable)

150 psf Live Load (unreducable)

• 16.5 psf SID Load

* For this side by side comparison the loading will be simplified to 150 psf on the lower bay + 80 psf on the upper bay

* No live load reductions

Span A-B ⇒ using Table A-14

$C_1 = 24"$ $\quad C_1/\ell_1 = 0.075$

$\ell_1 = 26.8' \Rightarrow 321.6"$ $\quad C_2/\ell_2 = 0.143$

$C_2 = 24"$

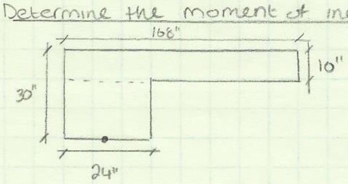
$\ell_2 = 14' \Rightarrow 168"$

$\Rightarrow M = 0.0845\, w_u \ell_2 \ell_1^2$

$\Rightarrow K = 4.196\, EI/\ell_1 = \frac{4.196\, E(114000)}{321.6} = 1487\, E_c$

$\Rightarrow COF = 0.514$

Determine the moment of inertia.



$$\bar{y} = \frac{(24\times20)(10) + (10\times168)(25)}{(24\times20)+(10\times168)} = 21.67$$

$$I = \left(\frac{24(20)^3}{12} + \frac{168(10)^3}{12}\right) + \left((24\times20)(21.67-10)^2 + (168\times10)(21.67-25)^2\right)$$

$$= 30{,}000 + 84000 = 114000\ in^4$$

Span B - C

$C_1/\ell_1 = 0.75$
$C_2/\ell_2 = 0.143$

$M = 0.0845\, w_u \ell_2 \ell_1^2$

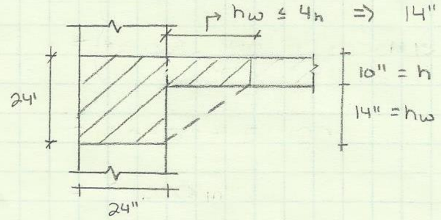
$K = 1487\, E_c$

$COF = 0.514$

Coef for Equivalent Columns

Column A
- the torsional member is the 24x24 beam
- torsional cross section is condition (c)

$h_w \leq 4h_n \Rightarrow 14'' \leq 40''$ ✓



$$C = \Sigma\left(1 - 0.63\frac{x}{y}\right)\frac{x^3 y}{3}$$

$$= \left(1 - 0.63\,\frac{24}{24}\right)\frac{24^3(24)}{3} + \left(1 - 0.63\left(\frac{10}{14}\right)\right)\frac{10^3(14)}{3}$$

$$= 40919 + 2567$$

$$= 43486\ \text{in}^4$$

$$K_t = \Sigma\,\frac{9EC}{\ell_2(1 - C_2/\ell_2)^3} = \frac{9E(43486)}{304\,(1 - 24/304)^3} = 1648E$$

(ℓ_2 = 25.33(12))

provision due to beam parallel to span

$K_t\,(I_{sb}/I_s)$

$I_{sb} = 114000$

$I_s = 1/12\,(168)(10)^3 = 14000$

$K_t(I_{sb}/I_s) = (1648\,E)(114000/14000) = 13419\,E$

$\Sigma K_c = K E I_c / l_c$ (From A-17)

$I_c = \frac{(24)^4}{12} = 27648$

Column Below + above

$l_c = 192''$

$l_u = 192 - 30 = 162''$

$l_c / l_u = 1.19$

$t_a = 25$

$t_b = 5$

$t_a / t_b = 5$

$\Rightarrow \Sigma K_c = \frac{(7.388) E (27648)}{192} \times 2 = 2128 E$

COF = 0.52

Kec

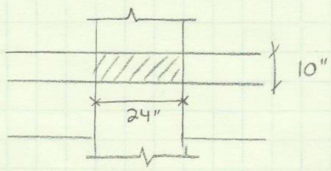
$\frac{1}{K_{ec}} = \frac{1}{\Sigma K_c} + \frac{1}{K_t}$

$\frac{1}{K_{ec}} = \frac{1}{2128 E} + \frac{1}{13419 E}$

$K_{ec_A} = 1837 E$ COF = 0.52

Colum B

- the torsional member is the slab



$$C = \left(1 - 0.63\,\frac{10}{24}\right)\frac{10^3(24)}{3} = 5900 \text{ in}^4$$

$$K_t = \frac{9E(5900)}{304(1 - 24/304)^3} = 223.5E$$

$$* \; k_t (I_s / I_{sb}) = 223.5\,(114000/14000) = 1820E$$

$$\Sigma K_c = KEI_c/\ell_c$$

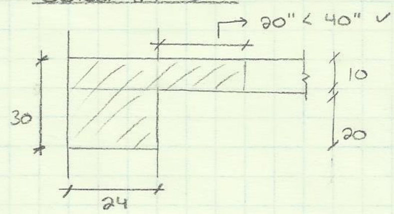
$$I = 27648$$

$$K_c = 2128E$$

$$K_{ec}: \quad \frac{1}{K_{ec}} = \frac{1}{2128E} + \frac{1}{1820E}$$

$$K_{ecB} = 981E \qquad COF = 0.52$$

Column C



$C = \left(1 - 0.63\left(\frac{24}{24}\right)\right)\frac{24^3(24)}{3} + \left(1 - 0.63\left(\frac{10}{44}\right)\right)\left(\frac{10^3 \cdot 44}{3}\right)$

$= 40919 + 12567$

$= 53486 \text{ in}^4$

$K_t = \frac{9E(53486)}{304(1 - 24/304)^3} = 2067E$

$* \ K_t(I_s/I_{sb}) = 2067E(114000/14000) = 16831E$

$\Sigma K_c =$

$I = 27648$

$K_c = 2128E$

$K_{ec} \Rightarrow \frac{1}{K_{ec}} = \frac{1}{2128E} + \frac{1}{16831E}$

$K_{ec_c} = 1889E$ $\quad$ COF = 0.52

Distribution Factors

$DF_{col\,A} = \frac{1837E}{1837E + 1487E} = 0.553$

$DF_{A-B} = \frac{1487E}{1837E + 1487E} = 0.447$

$DF_{B-A} = \frac{1487E}{1487E + 981E + 1487E} = 0.376$

$DF_{col\,B} = \frac{981E}{1487E + 981E + 1487E} = 0.248$

$DF_{BC} = \frac{1487E}{1487E + 981E + 1487E} = 0.376$

$D_{C-B} = \frac{1487E}{1487E + 1889E} = 0.440$

$D_{col\,C} = \frac{1889E}{1889E + 1487E} = 0.560$

Load Cases

Span A-B

$q_L = 80psf\,(14) = 1120plf$

$q_D = 16.5 + 150\,(10/12) = 141.5psf\,(14) = 1981\,plf$

$q_{beams} = 150\,(20 \times 24/144) = 500plf$

$q_u = 1.2(1981 + 500) + 1.6\,(1120) = 4769\,plf$

$M = 0.0845\,(4769)(25.33)^2 = 259^{k'}$

Span B-C

$q_L = 150\,(14) = 2100plf$

$q_D = 16.5 + 150\,(10/12) = 141.5\,(14) = 1981\,plf$

$q_{beams} = 150\,(20 \times 24/144) = 500plf$

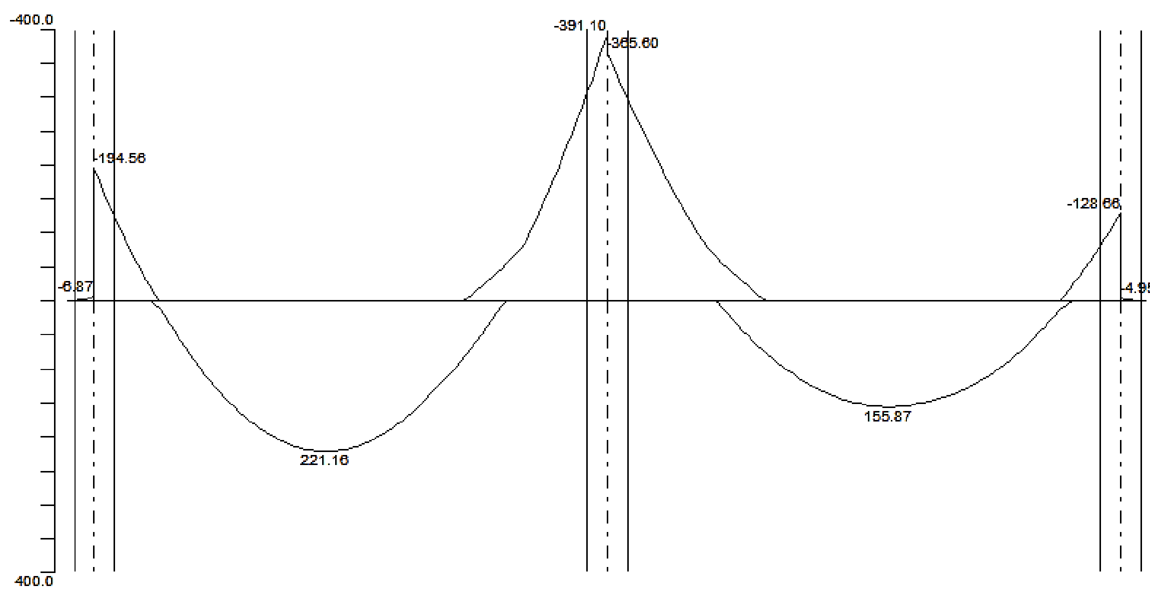
$q_u = 1.2\,(1981 + 500) + 1.6\,(2100) = 6337\,plf$

$M = 0.0845\,(6337)(25.33)^2 = 344^{k'}$

Moment Distribution

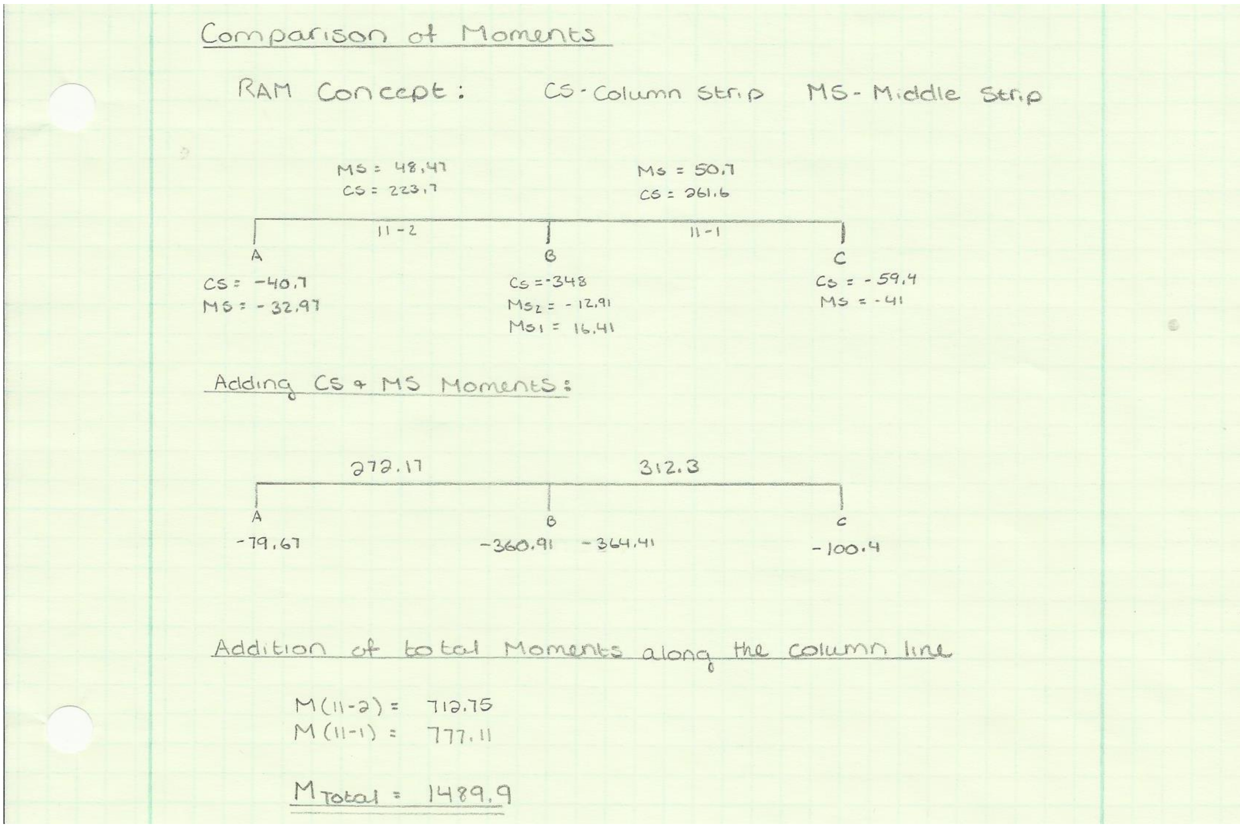
	Joint A		Joint B			Joint C	
		COF = 0.514			COF = 0.514		
	0.553 Col	0.447 Slab	0.376 Slab	0.248 Col	0.376 Slab	0.440 Slab	0.560 Col
FEM	0	259	-259	0	344	-344	0
B1	-143.2	-115.8	-32.0	-21.1	-32.0	151.4	192.6
C1		-16.4	-59.5		77.8	-16.4	
B2	9.1	7.3	-6.9	-4.5	-6.9	7.2	9.2
C2		-3.5	3.8		3.7	-3.5	
B3	1.9	1.6	-2.8	-1.9	-2.8	1.5	2.0
C3		-1.4	0.8		0.8	-1.4	
B4	0.8	0.6	-0.6	0.4	-0.6	0.6	0.8
Sum	-131.4	131.4	-356	-27	384	-203	203
		0		0		0	

SP Slab Output:



Joint C Joint B Joint A

Ram Concept Moments



Comparison of Hand Calculations and RAM Concept

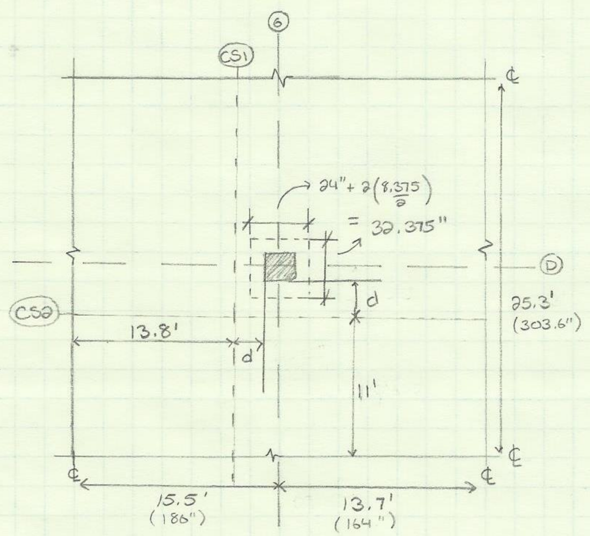
Design Moments – Per Joint						
Method	M_{A}-	M_{AB}+	M_{AB}-	M_{BC}-	M_{BC}+	M_{C}-
EFM/SP Slab	128.66	155.87	365.60	391.10	221.16	194.56
RAM Concept	79.67	272.17	360.91	364.41	312.30	100.40

Percent Different in Total Design Moments			
	Hand Calculations/SP Slab	RAM Concept	% Difference
Total Moment in Span A-B	650.13	712.75	9%
Total Moment in Span B-C	806.82	777.11	4%
Total Moment in Both Spans	1456.95	1489.86	2%

Appendix C.2: One-way and Two-way Shear Checks

The following are hand calculations for one-way and two-way shear at column D6.

Column 6D



Column = 24" x 24"
Slab t = 10"
cover = 0.75"
rebar = #7 (long + trans)

d = 10 - 0.75 - 7/8 = 8.375 in

Loads

D = 16.5 psf
SW = 150 (10/12) = 125 psf
L = 150 psf

$W_u = 1.2(16.5 + 125) + 1.6(150)$
$= 410 \text{ psf}$
$= 0.410 \text{ ksf}$

$V_u \le \phi V_n = \phi V_c$

Wide Beam (one-way) Shear

CS1:

$V_u = 0.410(13.8' \times 25.3') = 143.1 \text{ kips}$

$V_c = 2\lambda\sqrt{f'_c}\, b_w d = 2(1)\sqrt{4000}(25.3 \times 12)(8.375)/1000 = 322 \text{ kips}$

$\phi V_c = 0.75(322) = 241.5^k$

$\Rightarrow 241.5^k > 143.1^k$ ✓

CS2:

$V_u = 0.410(11' \times 29.2') = 131.7^k$

$V_c = 2(1)\sqrt{4000}(29.2 \times 12)(8.375)/1000 = 371.2^k$

$\phi V_c = 0.75(371.2) = 278.4^k$

$\Rightarrow 278.4^k > 131.7^k$

⇒ Passes for one-way Shear

Shear output from RAM Concept

CS1: At the column face

	Max Demand	Max Capacity
LMS	5.635	64.44
CS	130.8	177.3
RMS	7.127	64.4
	143.6 k	306.1 k

CS2: At the column face

	Max Demand	Max Capacity
LMS	7.378	79.41
CS	127.1	159.7
RMS	6.578	63.48
	141.1 k	302.6 k

% Difference between Hand Calcs & RAM Concept

Max Demand ⇒ 0%

Max Capacity ⇒ $\frac{302.6 - 278.4}{278.4} \times 100 = 8\%$

Punching (Two-way) Shear

$V_u = 0.410\left[25.3 \times (15.5 + 13.7)\right) - \left(\frac{32.375}{12}\right)^2\right] = 300^K$

V_c :
- $(2 + 4/\beta)\, \lambda \sqrt{f'c}\, b_o d$
- $\left(\frac{\alpha_s d}{b_o} + 2\right) \lambda \sqrt{f'c}\, b_o d$
- min: $4 \lambda \sqrt{f'c}\, b_o d$

$\beta = 24/24 = 1$

$\lambda = 1.0$

$\alpha = 40$

$b_o = (32.375) \times 4 = 129.5 \text{ in}$

V_c :
- $(2 + 4/1) = 6$
- $\left(\frac{40(8.375)}{129.5} + 2\right) = 4.6$
- min: 4

→ $4\lambda\sqrt{f'c}\, b_o d$ controls

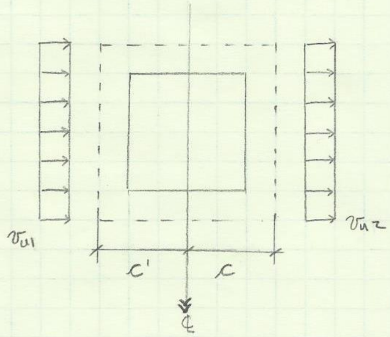
$V_c = 4(1)\sqrt{4000}\,(129.5)(8.375)/1000 = 274.4^K$

$\phi V_c = 0.75(274.4) = 206^K$

$\Rightarrow 206^K < 300^K \Rightarrow$ Shear reinforcement required

Punching Shear - eccentric shear considering moment

-moment about y-axis



$$v_{u1} = \frac{V_u}{b_o d} + \frac{\gamma_v M_u (c')}{J_c}$$

$$v_{u2} = \frac{V_u}{b_o d} - \frac{\gamma_v M_u (c)}{J_c}$$

Knowns

$V_u = 300^k$

$b_o d = 129.5(8.375) = 1085 \text{ in}^2$

$c = c' = 32.375/2 = 16.2 \text{ in}$

$$J_c = \frac{1}{2} b_1^2 b_2 d + \frac{b_1^3 d}{6} + \frac{b_1 d^3}{6}$$

$$= \frac{1}{2}(32.375)^2(32.375)(8.375) + \frac{(32.375)^3(8.375)}{6} + \frac{(32.375)(8.375)^2}{6}$$

$$= 142097 + 1463 + 378$$

$$= 143938 \text{ in}^4$$

$$\gamma_f = \frac{1}{1 + \frac{2}{3}\sqrt{b_1/b_2}} = \frac{1}{1 + \frac{2}{3}\sqrt{1}} = 0.6$$

$\gamma_v = (1 - \gamma_f) = (1 - 0.6) = 0.4$

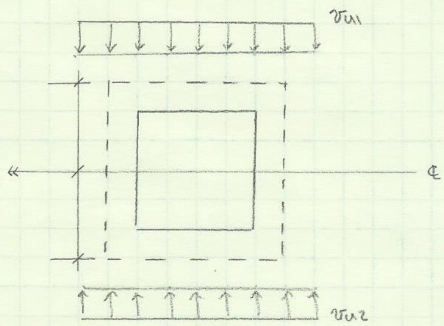
$M_u = 4.49^{1k}$

$$v_{u1} = \left[\frac{300^k}{1085 \text{ in}^2} + \frac{(0.4)(4.49^{1k} \times 12)(16.2)}{143938}\right] 1000 = 279 \text{ psi}$$

$$v_{u2} = \left[\frac{300^k}{1085 \text{ in}^2} - \frac{(0.4)(4.49 \times 12)(16.2)}{143{,}938}\right] 1000 = 274 \text{ psi}$$

$\phi V_c = 206/(1085) \times 1000 = 189.9 \text{ psi}$

- moment about X-axis



$V_u = 300^k$
$b_o d = 1085 in^2$
$c = c' = 16.2 in$

$J_c = 143938 in^4$
$\gamma_v = 0.4$

$M_u = 6.92^{'k}$

$$v_{u1} = \left[\frac{300}{1085} + \frac{(0.4)(6.92 \times 12)(16.2)}{143,938}\right] 1000 = 280 psi$$

$$v_{u2} = \left[\frac{300}{1085} - \frac{(0.4)(6.92 \times 12)(16.2)}{143,938}\right] 1000 = 273 psi$$

$\phi v_c = 189.9 psi < 280 psi \Rightarrow$ Shear Reinf. required

RAM Concept Output (from punching shear audit

$b_o = 129.5 in$
$d = 8.375 in$

max absolute stress = 284.6psi
Allowable Stress = 189.7 psi

% Difference between hand calcs & RAM Concept

Max Absolute = $\frac{284.6 - 280}{280} \times 100 = 1.6\%$

Allowable Stress = $\frac{189.7 - 189.9}{189.7} \times 100 = 0.1\%$

Appendix C.3: Shear Stud Rail Check

RAM Concept specifies the number of stud rails and the number of studs per rail required for two-way shear reinforcement. In order to check this specified design, Decon STDesign was used. Decon STDesign is a program that designs shear stud rails for individual columns.

The version of Decon used to verify the required stud rails uses ACI318-05, unlike RAM Concept which used ACI318-11 as the design code. In order to perform an accurate verification, RAM Concept was run using ACI318-05 as the design code. The results were then compared, and can be seen in **Table C1**.

Note: Both designs were completed using ½" studs

Shear Stud Rail Design		
	RAM Concept	Decon STDesign
Stud Rails per Column	12	12
Studs per Stud Rail	12	13
Stud Spacing	3.75 in	3.75

Table C1: Shear Studrail Comparison

These results show that RAM Concept's design was accurate. Further output from both programs can be seen on the next few pages.

The following is output from Decon STDesign and RAM Concept. Key comparisons between Decon STDesign and RAM Concept were the studrail designs and the calculated shear resistances/stresses.

STDesign 3.1 Decon® Studrail® Design

Connection 1, Page 1

PROJECT DATA

Project name: Untitled Project
Project number: UVA Column 6D Check
Engineer: MAC
Date: 06 February 2014
File path: G:\THESIS\Spring\Stud Rail Check\Column 6D studrails.srp

INPUT DATA

Connection name: Connection 1

General:
Design code: ACI 318-05
System of units: US (in, k, k-ft, psi)

Connection:
Connection location: Interior
Column dimension, c_x: 24.00 in
Column dimension, c_y: 24.00 in

Loads:
V_u: 292.4 k
M_{ux}: -6.920 k-ft
M_{uy}: -4.490 k-ft

Slab:
Effective depth, d: 8.375 in
Slab thickness: 10.00 in
Top cover: 0.750 in
Bottom cover: 0.750 in
Concrete compressive strength, f'_c: 4000 psi
Concrete density: Normal weight
Prestress, f_{pc}: 0.000 psi

Studrails:
2003/2006 IBC ductility requirement: No
Stud yield strength, f_{yv}: 5.000×10^4 psi
Stud diameter: 0.5 in
Typical stud spacing, S: Automatic
End stud spacing, S_0: Automatic
Number of studrails: Automatic

Openings:
None.

Connection 1, Page 2

STUDRAIL SUMMARY

Number of studrails per column: 12
Number of studs per studrail: 12
Stud diameter: 0.5 in
Typical stud spacing, S: 3.750 in
End stud spacing, S_0: 3.750 in
Overall height of studrail: 8.500 in

OUTPUT DATA

Inner Critical Section (d/2 outside of column face):

Common Properties

Area, A_c: 1085 in^2
Critical Section Perimeter, b_0: 129.5 in

Natural Axis Properties

Centroid coordinate, e_x: 0.0 in
Centroid coordinate, e_y: 0.0 in
Section moment of inertia, I_x: 1.895×10^5 in^4
Section moment of inertia, I_y: 1.895×10^5 in^4
Section product of inertia, I_{xy}: 0.0 in^4

Principal Axis Properties

Centroid coordinate, e_1: 0.0 in
Centroid coordinate, e_2: 0.0 in
Section moment of inertia, I_1: 1.895×10^5 in^4
Section moment of inertia, I_2: 1.895×10^5 in^4
Principal axis rotation, (theta): 0.0 degrees
Moment fraction, γ_{v1}: 0.400
Moment fraction, γ_{v2}: 0.400

Natural Axis Loads

V_u: 292.4 k
M_{ux}: -6.920 k-ft
M_{uy}: -4.490 k-ft

Principal Axis Loads

V_u: 292.4 k
M_{u1}: -6.920 k-ft
M_{u2}: -4.490 k-ft

Stresses

Maximum shear stress, v_u: 274.3 psi
at x = -16.19 in, y = 16.19 in

Shear resistance, ϕv_n (concrete only): 189.7 psi
Shear resistance, ϕv_n (with Studrails): 276.8 psi
Shear resistance, ϕv_n (upper limit): 284.6 psi

Outer Critical Section (d/2 outside of reinforced zone):

Common Properties

Area, A_c: 3156 in^2
Critical Section Perimeter, b_0: 376.8 in

Natural Axis Properties

Centroid coordinate, e_x: 0.0 in
Centroid coordinate, e_y: 0.0 in
Section moment of inertia, I_x: 5.251×10^6 in^4
Section moment of inertia, I_y: 5.251×10^6 in^4
Section product of inertia, I_{xy}: 0.0 in^4

Principal Axis Properties

Centroid coordinate, e_1: 0.0 in
Centroid coordinate, e_2: 0.0 in
Section moment of inertia, I_1: 5.251×10^6 in^4
Section moment of inertia, I_2: 5.251×10^6 in^4
Principal axis rotation, (theta): 0.0 degrees
Moment fraction, γ_{v1}: 0.400
Moment fraction, γ_{v2}: 0.400

Natural Axis Loads

V_u: 292.4 k
M_{ux}: -6.920 k-ft
M_{uy}: -4.490 k-ft

Principal Axis Loads

V_u: 292.4 k
M_{u1}: -6.920 k-ft
M_{u2}: -4.490 k-ft

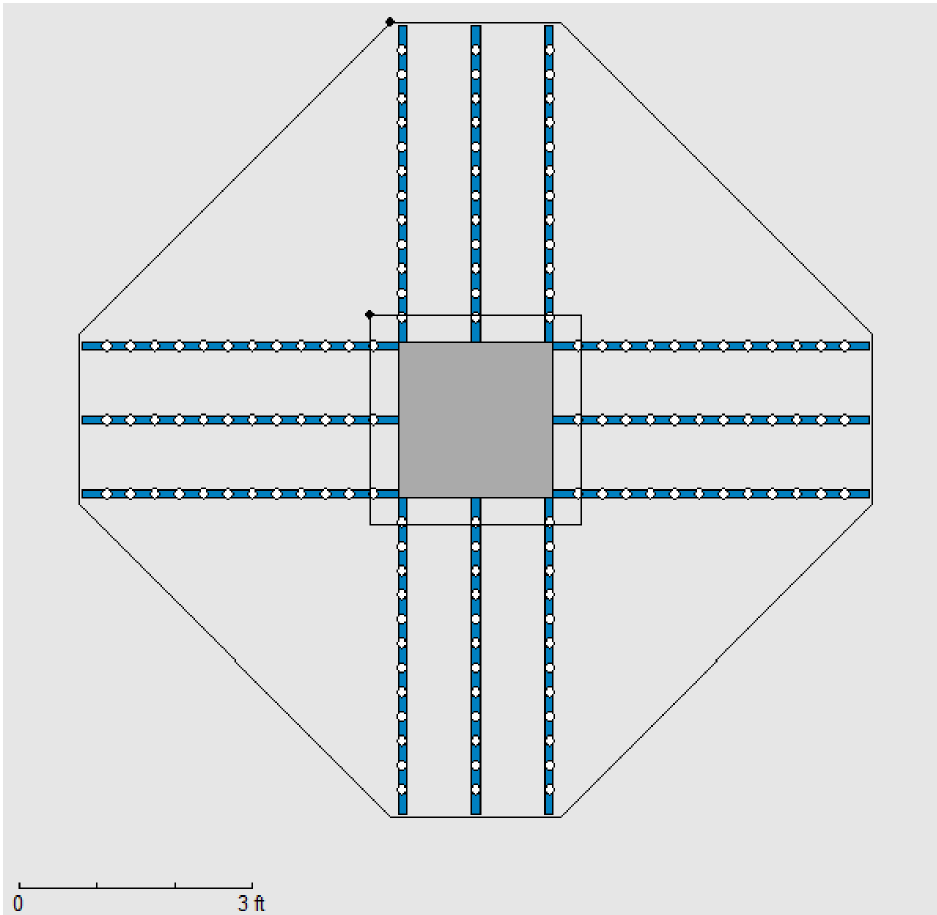
Stresses

Maximum shear stress, v_u: 93.09 psi
at x = -13.11 in, y = 61.19 in

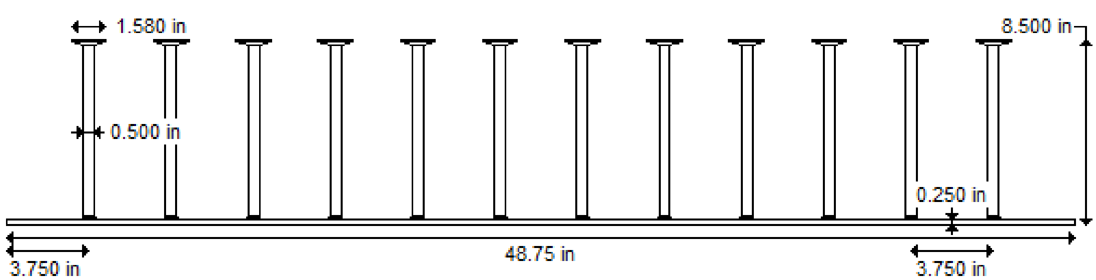
Shear resistance, ϕv_n: 94.87 psi

Design Comments:
None.

PLAN VIEW



ELEVATION VIEW



RAM Concept

```
Design At Start of Final Design Check
12 Total Rails
13 Studs/Rail
Stud Area = 0.196 sq. in.
Stud Yield Stress = 50 ksi
First Stud Spacing = 3.375 inches
Typical Stud Spacing = 3.75 inches
--------------------------------------------------------------

Gamma-F Fractions about Punch Check Axes
Min Mr Fraction = -26.99 kip-ft
Max Mr Fraction = 38.51 kip-ft
Min Ms Fraction = -30.7 kip-ft
Max Ms Fraction = 50.26 kip-ft

Analyzing 1 Column Sections

    Section Analysis - Audit ID = 1
        Section Properties:
            Perimeter Length = 130.5 inches
            Perimeter Average Depth = 8.625 inches
            Properties about Punch Check Axes
                Elastic Centroid Location:
                    x = 0 inches
                    y = 0 inches
                Ix = 199600 in^4
                Iy = 199600 in^4
                Ixy = 0 in^4
            Properties about Principal Axes
                Angle to Principal x-axis = 0 degrees
                Ix = 199600 in^4
                Iy = 199600 in^4
                Ixy = 0 in^4
                x width = 32.62 inches
                y width = 32.62 inches
                Gamma-Vx = 0.4
                Gamma-Vy = 0.4

        Maximum Absolute Stress = 274.1 psi
        Allowable Stress = 189.7 psi
        Unreinforced Stress Ratio = 1.445
        Reinforced Strength Ratio = 0.9964
```

```
Analyzing 1 Cutoff Sections

    Section Analysis - Audit ID = 2
        Section Properties:
            Perimeter Length = 395.9 inches
            Perimeter Average Depth = 8.625 inches
            Properties about Punch Check Axes
                Elastic Centroid Location:
                    x = 0.003937 inches
                    y = 0.003937 inches
                Ix = 6240000 in^4
                Iy = 6240000 in^4
                Ixy = 0.01513 in^4
            Properties about Principal Axes
                Angle to Principal x-axis = 0 degrees
                Ix = 6240000 in^4
                Iy = 6240000 in^4
                Ixy = 0.01513 in^4
                x width = 129.4 inches
                y width = 129.4 inches
                Gamma-Vx = 0.4
                Gamma-Vy = 0.4

        Maximum Absolute Stress = 61.91 psi
        Allowable Stress = 94.87 psi
        Unreinforced Stress Ratio = 0.6525


Status:
    OK with SSR
```

Appendix D: Deflections

RAM Concept uses an effective curvature ratio (ECR) to calculate both instantaneous and long term deflections for both cracked and uncracked sections. The default ECR is 3.35. This value comes from ACI 209. The problem with this value is that many practicing engineers feel that it is too conservative.

ACI318-11 Section 9.5.2.5 says that for long term deflections a factor of 2 may be used for calculating deflections over a period of 5 years or more if no compression reinforcement is used. A factor of 1 is used to account for short term deflections. Thus, an ECR = 3 is used in RAM Concept's calculation of long term deflections.

To account for the effects of cracked sections RAM Concept uses a simpler approach that most often gives a conservative design. Once the moment due to the service load exceeds the moment due to cracking the program then considered the ratio of the moment due to service loads to the moment due to cracking. The ECR is then multiplied by this ratio. For example:

$M_{service}/M_{crack} = 2$
ECR = 3

New ECR: 3 x 2 = 6

RAM Concept also does not account for the difference in live load vs dead load. A weighted average of the loads can be calculated by hand to achieve a lower ECR. This is done by using the following equation:

$$\frac{Live\ Load}{Live + Dead}(1.6) + \frac{Dead\ Load}{Live + Dead}(ECR) = \ New\ ECR$$

The 1.6 factor comes from the approximation of 30% of the sustained live load multiplied by the creep and shrinkage factor plus 1 from the instantaneous deflections. In this case the creep and shrinkage factor is 2 of which 30% is 0.6.

The limit for deflections is L/480. This comes from ACI318-11 Table 9.5(b). It is expected that there will be non-structural elements likely to be damaged by large deflections. Edge deflections will be held to a stricter criterion of L/600 to prevent danged to the masonry façade.

The following pages show the process of checking deflections and making adjustments so they pass.

Deflection Adjustments

It was determined that the bays located between column lines 5-7 and E-C were the worst case conditions for deflections in the slab. This was expected due to the large spans of 27'-4" and 31'-0". **Figure D1** below shows the location of these bays with respect to the floor plan.

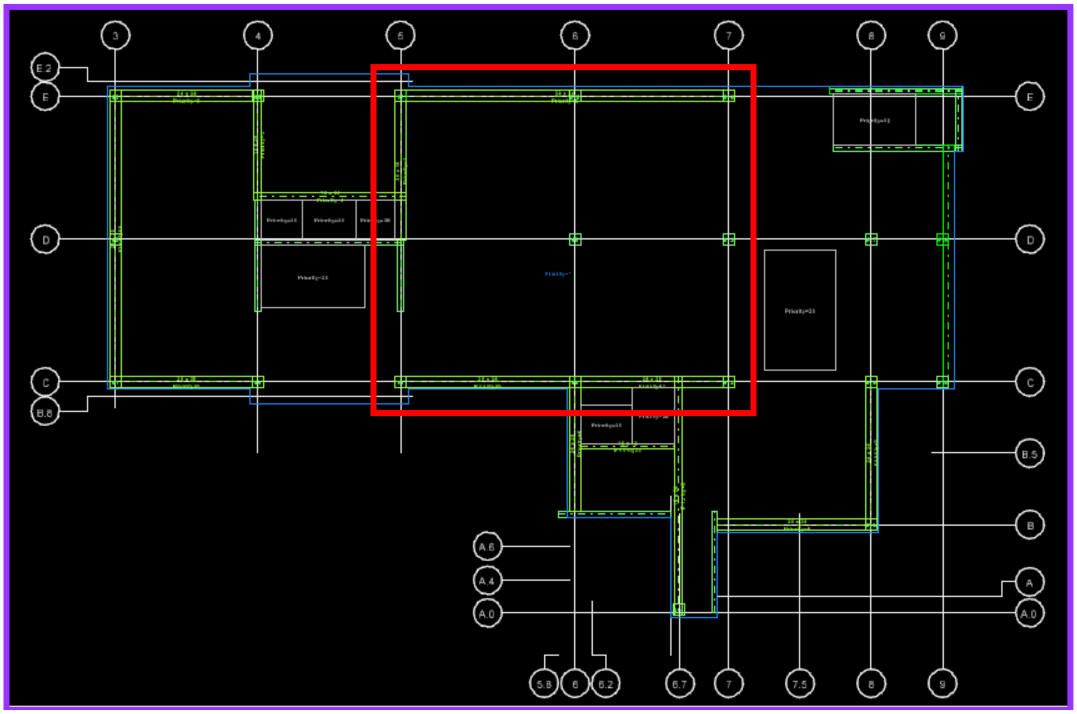


Figure D1: Bays with Worst Case Deflections

Options if deflections fail:

- Use a weighted average to adjust ECR
- Add compression reinforcement
- Add drop panel/shallow beam
    - This option is the least favorable do to the fact that it means increased formwork, and can have a negative impact on the architecture and the other building system.

Initial Deflections with ECR = 3

The initial deflection contours are shown in **Figure D2**, and initial deflections are shown in **Table D1**. No adjustments have been made to the ECR.

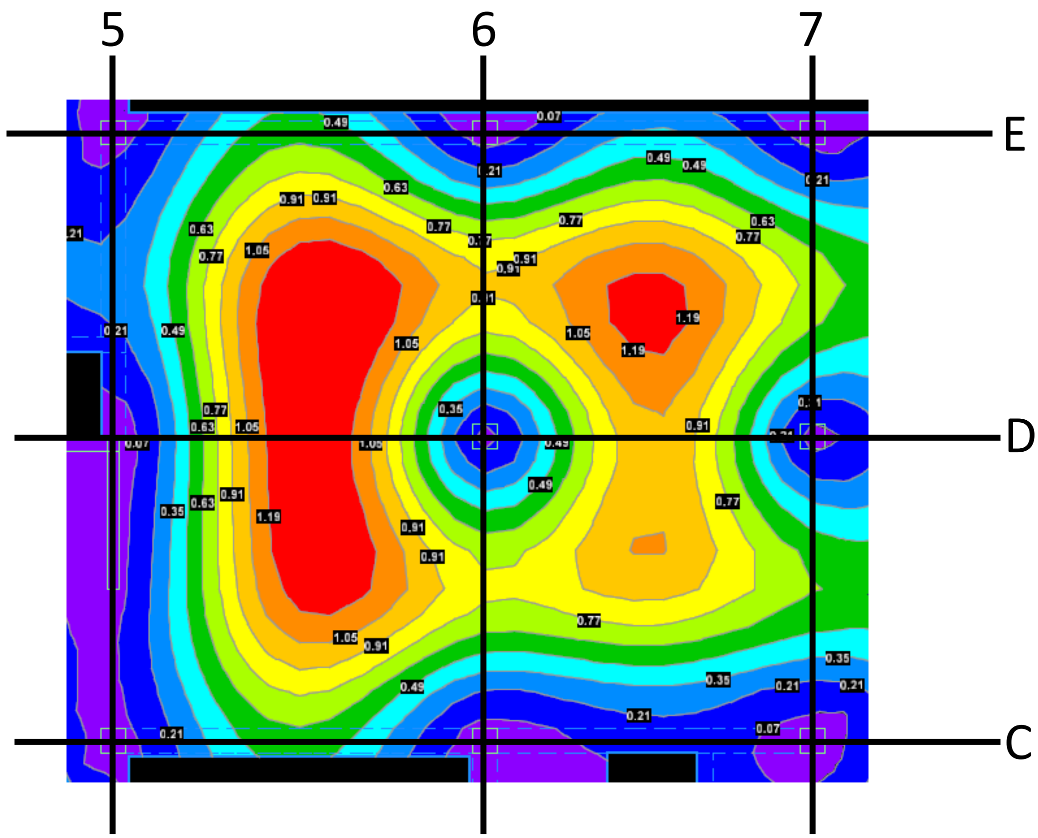


Figure D2: Initial Deflection Contours

Span	Span Length (FT)	Deflection	L/480	Pass/Fail
5D - 6D	31	1.33	0.775	Fail
6D - 7D	27.33	1.02	0.683	Fail
5E - 6D	40	1.43	1.0	Fail
6E - 7D	37.33	1.24	0.933	Fail
5C- 6D	40	1.33	1.0	Fail

Table D1: Initial Deflections

From this trial it was determined that Span 5D-6D was the controlling span for deflections.

Trial 1 – Weighted Loads

The first alteration was the use of the weighted loading condition. Calculation of the new ECR was:

$$\frac{80}{80+141.5}(1.6)+\frac{141.5}{80+141.5}(3) = 2.5$$

Where:

Live Load = 80 psf (conservative since bay sees both 80psf and 150 psf)

Dead Load = 141.5 psf (Slab self-weight of 125psf and 16.5psf misc. dead load)

Figure D3 shows the deflection contours along with **Table D2** which shows the new deflections.

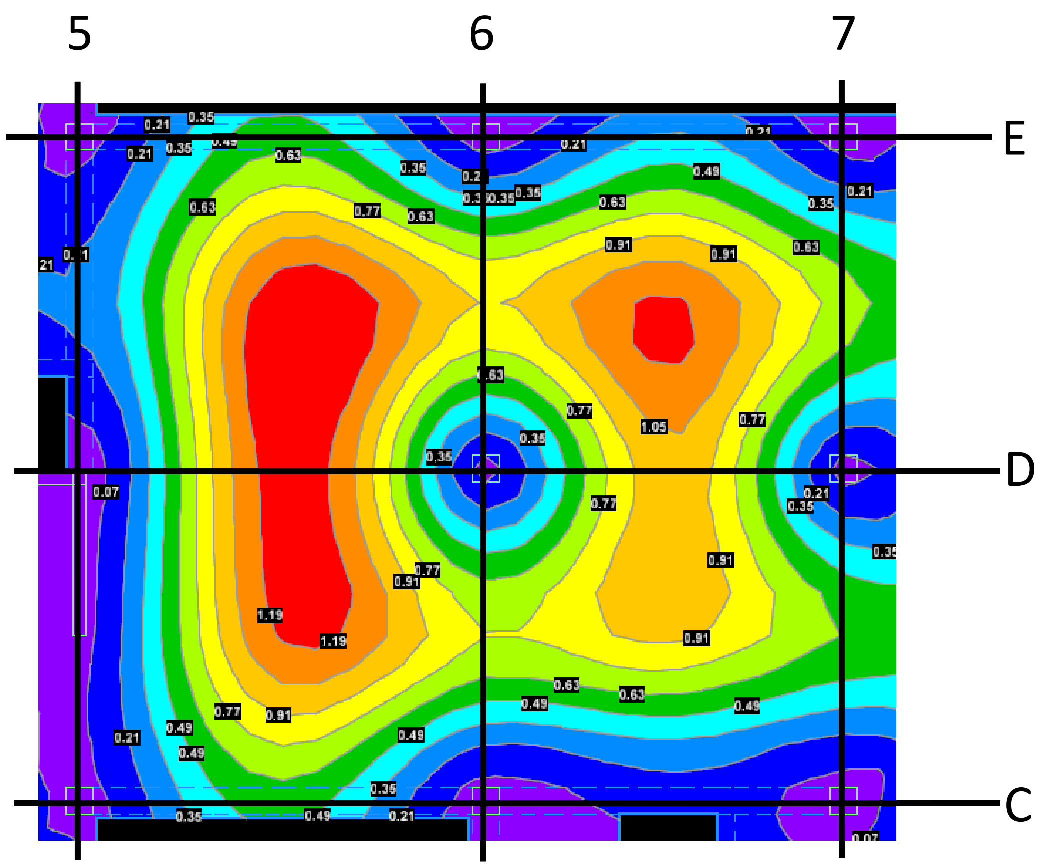


Figure D3: Initial Deflection Contours

Span	Span Length (FT)	Deflection	L/480	Pass/Fail
5D - 6D	31	1.27	0.775	Fail

Table D2: Critical Deflection with Weighted Loading Condition

Accounting for the weighted loading condition made a small difference but did not adjust the output enough to meet criteria.

Trial 2 – Compression Reinforcement

The second alteration was the use of compression reinforcement. By adding compression reinforcement the long term deflection factor changes (ACI318-11 Section 9.5.2.5). Once this deflection factor changes the factor used in the weighted average also changes.

To determine the compression steel required to meet the deflection limit, the required ECR was determined. To meet L/480 the deflection of the slab needed to be limited to 0.775 in (from the 31'-0" span). After several runs of the program it was determined that an ECR of less than 1 was required to meet this criterion. **Table D3** show the deflections based on the ECR.

ECR	Deflection (in)
2.5	1.27
1.5	1.1
1	1.01

Table D3: ECR vs. Deflection

This requirement was unrealistic due to the fact that at a minimum the instantaneous deflections are 1. Therefore it was determined that a drop panel or a shallow beam would be required to limit the deflections.

Trial 3 – Drop Panels and Shallow Beams

Before adding a shallow beam along the span 5D – 6D a drop panel was added to the column at 6D. This column was a critical column when dealing with punching shear, so a drop panel would also eliminate the need for shear stud rails.

The first drop panel trial size was based on the minimum size required to resist punching shear, and was made square for simplification. The dimensions are shown in **Table D4**.

Column	-X	+X	-Y	+Y	Thickness
6D	6	6	6	6	16

TableD4: Dimension of Drop Panel at 6D

Deflections with this drop panel and an ECR of 2.5 were calculated, and the deflection was 1". The deflection for each of the critical spans can be seen in **Table D5**.

Span	Span Length (FT)	Deflection	L/480	Pass/Fail
5D - 6D	31	1.0	0.775	Fail
6D - 7D	27.33	0.669	0.683	Pass
5E - 6D	40	1.07	1.0	Fail
6E - 7D	37.33	0.971	0.933	Fail
5C - 6D	40	1.04	1.0	Fail

Table D5: Deflections with Addition of Drop Panel

Since the slab was still failing in multiple locations it was decided that a larger drop panel (7'x7') would be provided. **Table D6** shows the resulting deflections.

Span	Span Length (FT)	Deflection	L/480	Pass/Fail
5D - 6D	31	0.955	0.775	Fail
6D - 7D	27.33	0.592	0.683	Pass
5E - 6D	40	1.03	1.0	Fail
6E - 7D	37.33	0.92	0.933	Pass
5C - 6D	40	0.986	1.0	Pass

Table D6: Deflections with 7'x7' Drop Panel

At this point the deflection failures were concentrated between column line 5 and 6. There were two options:

- Increase the drop panel size to an 8'x 8' drop
- Add a shallow beam (7 x 4" below the slab) along column line D between column line 5 and 6

Both options were considered in order to choose the best design. The resulting deflections for the added drop panel are shown in **Table D7**, and the resulting deflections for the shallow beam are shown in **Table D8**.

Span	Span Length (FT)	Deflection	L/480	Pass/Fail
5D - 6D	31	0.943	0.775	Fail
6D - 7D	27.33	0.614	0.683	Pass
5E - 6D	40	1.02	1.0	Fail
6E - 7D	37.33	0.943	0.933	Fail
5C - 6D	40	0.974	1.0	Pass

Table D7: Deflections with 8'x8' Drop Panel

Span	Span Length (FT)	Deflection	L/480	Pass/Fail
5D - 6D	31	0.709	0.775	Pass
6D - 7D	27.33	0.511	0.683	Pass
5E - 6D	40	0.875	1.0	Pass
6E - 7D	37.33	0.817	0.933	Pass
5C - 6D	40	0.827	1.0	Pass

Table D8: Deflections with Shallow Beam

It was determined that a larger drop panel was not a good option. Even though deflections at span 5D-6D and 5E-6D improved, many of the deflections at other locations worsened.

The 7' x 7' drop cap with the 4" shallow beam proved to be the most effective in reducing the deflections.

Appendix E: Reinforcement

Note: For span designations please see the reinforcement plan within the body of the report.

Calculation of Additional Bottom Bars

Latitude Reinforcement					
Span	Span Width (FT)	A_{req} (in^2/ft)	A_{prov} (in^2/ft)	Additional Reinforcement Required (in^2/ft)	Additional Bars
MS - 1	16	0.31	0.23	0.08	5
CS - 1	12.4	0.37	0.23	0.14	#5 @ 16
MS - 2	16	0.31	0.23	0.08	5
CS - 2	8.6	0.29	0.23	0.06	4
MS - 3	6.15	0.25	0.23	0.02	2
CS - 3	7.17	0.37	0.23	0.14	#5 @ 16
MS - 4	15.3	0.29	0.23	0.06	4
CS - 4	12.4	0.62	0.23	0.39	#5 @ 8
MS - 5	15.3	0.29	0.23	0.06	4
CS - 5	12.4	0.46	0.23	0.23	#5 @ 16
CS - 7	12.5	0.25	0.23	0.02	2
MS - 6	9.8	0.25	0.23	0.02	2

Table E1: Additional Bottom Latitude Reinforcement

Longitude Reinforcement					
Span	Span Width (FT)	A_{req} (in^2/ft)	A_{prov} (in^2/ft)	Additional Reinforcement Required (in^2/ft)	Additional Bars
MS - 7	7.3	0.31	0.23	0.08	5
MS - 8	15.3	0.27	0.23	0.04	3
MS - 9	15.3	0.27	0.23	0.04	3
CS - 10	12.7	0.31	0.23	0.08	5
CS - 11	12.7	0.34	0.23	0.11	6
MS - 10	14.7	0.27	0.23	0.04	3
MS - 11	14.7	0.31	0.23	0.08	5
CS - 13	12.7	0.27	0.23	0.04	3

Table E2: Additional Bottom Longitude Reinforcement

Calculation of Additional Top Bars

Latitude Reinforcement					
Span	Span Width (FT)	A_{req} (in^2/ft)	A_{prov} (in^2/ft)	Additional Reinforcement Required (in^2/ft)	Additional Bars
MS - 1	16	0.74	0.23	0.51	#5 @ 4
CS - 1 (Left)	12.4	0.37	0.23	0.14	#5 @ 16
CS - 1 (Right)	12.4	0.53	0.23	0.30	#5 @ 8
MS - 2/3	16	0.37	0.23	0.14	#5 @ 16
CS - 2 (Left)	7.15	0.37	0.23	0.14	#5 @ 16
CS - 2 (Right)	7.15	0.53	0.23	0.30	#5 @ 8
MS - 3/5	9.4	0.46	0.23	0.23	#5 @ 16
CS - 3 (Left)	7.17	0.37	0.23	0.14	8
CS - 3 (Right)	7.17	0.37	0.23	0.14	8
MS - 4	15.3	0.41	0.23	0.18	#5 @ 16
CS - 4 (Left)	12.4	1.24	0.23	1.01	#5 @ 2
CS - 4/5	12.4	1.86	0.23	1.63	#5 @ 2
CS - 5/6	12.4	0.62	0.23	0.39	#5 @ 16
CS - 6 (Right)	12.4	0.25	0.23	0.02	2
CS - 7 (Left)	12.5	0.53	0.23	0.3	#5 @ 8
CS - 7(Right)	12.5	0.31	0.23	0.08	5

Table E3: Additional Top Latitude Reinforcement

Longitude Reinforcement					
Span	Span Width (FT)	A_{req} (in^2/ft)	A_{prov} (in^2/ft)	Additional Reinforcement Required (in2/ft)	Additional Reinforcement
MS - 7	19.9	0.41	0.23	0.18	#5 @ 16
CS - 8 (Left)	9.2	0.31	0.23	0.08	5
CS - 8 (Right)	9.2	0.41	0.23	0.18	#5 @ 16
CS - 9 (Left)	12.7	0.37	0.23	0.14	#5 @ 16
CS - 9 (Right)	12.7	0.27	0.23	0.04	3
MS - 8/9	21.5	0.31	0.23	0.08	5
CS -10 (Left)	12.7	0.62	0.23	0.39	#5 @ 8
CS - 10/11	12.7	0.93	0.23	0.7	#5 @ 4
CS - 11 (Right)	12.7	0.34	0.23	0.11	6
MS - 10 (Left)	14.7	0.37	0.23	0.14	#5 @ 16
MS - 10/11	14.7	0.31	0.23	0.08	5
CS - 14 (Left)	14.6	0.37	0.23	0.14	#5 @ 16
CS - 12/14	12.7	0.46	0.23	0.23	#5 @ 16
CS - 12/13	12.7	0.74	0.23	0.51	#5 @ 4
CS - 13	12.7	0.25	0.23	0.02	2
CS - 15 (Left)	9.5	0.62	0.23	0.39	#5 @ 8
CS - 15 (Right)	9.5	0.31	0.23	0.08	5

Table E4: Additional Top Longitude Reinforcement

Appendix F: Column Design

Figure F1 below shows the calculation of the total factored axial load on each column at level 1. Also listed is the total factored moment in the r-direction (x-direction) and s-direction (y-direction) taken from RAM Concept. The worst case axial load and moments are highlighted in red while the possible critical cases for combined axial and moment are highlighted in pink.

Table F1 below shows the comparison of required strength to available strength of these critical columns.

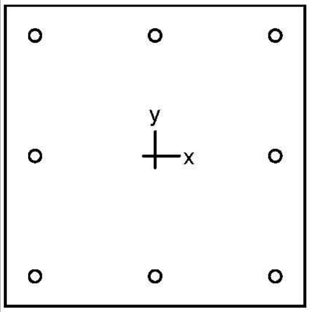
Column	φMn/Mu	φPn/Pu
3D	3.10	1.07
6E	3.40	1.25
6D	7.74	1.02
6C	4.49	1.02
7C	7.53	1.01
7E	4.53	1.44
8B	6.26	2.49

Table F1: Column Capacity

Column Location	Level	Trib Area (SF)	Floor to Floor Height (FT)	Floor Dead Loads(PSF)	Column Self Weight (lbs)	Beam Self Weight (lbs)	Wall Load (lbs)	Live (PSF)	Reduced Live Load (PSF)	Floor D*A$_T$	L*A$_T$	L$_r$*A$_T$	1.2D	1.6L	0.5L$_r$	Total	Column Total (K)	Mr	Ms
3E	Lower Roof	178	6	146	-	10765	27345	30	N/A	26020	-	5347	76956	-	2673	79630	695	31.34	56.89
	Level 6	178	18	135	10800	10765	39562	80	N/A	24060	14258	-	102225	22812	-	125038			
	Level 5	178	16	135	9600	10765	37235	80	N/A	24060	14258	-	97992	22812	-	120805			
	Level 4	178	16	135	9600	10765	37235	80	N/A	24060	14258	-	97992	22812	-	120805			
	Level 3	178	16	135	9600	10765	37235	80	N/A	24060	14258	-	97992	22812	-	120805			
	Level 2	178	18	135	10800	10765	41889	80	N/A	24060	14258	-	105018	22812	-	127830			
3D	Lower Roof	321	6	146	-	12665	27926	30	N/A	46837	-	9624	104915	-	4812	109727	1123	10.18	89.77
	Level 6	321	18	135	10800	12665	39562	150	N/A	43309	48121	-	127603	76993	-	204596			
	Level 5	321	16	135	9600	12665	37235	150	N/A	43309	48121	-	123370	76993	-	200364			
	Level 4	321	16	135	9600	12665	37235	150	N/A	43309	48121	-	123370	76993	-	200364			
	Level 3	321	16	135	9600	12665	37235	150	N/A	43309	48121	-	123370	76993	-	200364			
	Level 2	321	18	135	10800	12665	41889	150	N/A	43309	48121	-	130396	76993	-	207389			
3C	Lower Roof	178	6	146	-	12665	27926	30	N/A	26020	-	5347	79934	-	2673	82608	809	37.67	48.97
	Level 6	178	18	135	10800	12665	39562	150	N/A	24060	26733	-	104505	42773	-	147278			
	Level 5	178	16	135	9600	12665	37235	150	N/A	24060	26733	-	100272	42773	-	143046			
	Level 4	178	16	135	9600	12665	37235	150	N/A	24060	26733	-	100272	42773	-	143046			
	Level 3	178	16	135	9600	12665	37235	150	N/A	24060	26733	-	100272	42773	-	143046			
	Level 2	178	18	135	10800	12665	41889	150	N/A	24060	26733	-	107297	42773	-	150071			
4E	Lower Roof	232	6	146	-	7388	27926	30	28	33838	-	6953	82983	-	3477	86460	715	17.15	26.22
	Level 6	232	18	135	10800	7388	39562	80	76	31289	17553	-	106847	28085	-	134932			
	Level 5	232	16	135	9600	7388	37235	80	59	31289	13770	-	102614	22032	-	124646			
	Level 4	232	16	135	9600	7388	37235	80	52	31289	12094	-	102614	19350	-	121964			
	Level 3	232	16	135	9600	7388	37235	80	48	31289	11094	-	102614	17751	-	120365			
	Level 2	232	18	135	10800	7388	41889	80	45	31289	10412	-	109640	16660	-	126300			
4C	Lower Roof	160	6	146	-	6333	27926	30	N/A	23299	-	4787	69069	-	2394	71463	722	19.58	31.64
	Level 6	160	18	135	10800	6333	39562	150	N/A	21543	23937	-	93886	38299	-	132185			
	Level 5	160	16	135	9600	6333	37235	150	N/A	21543	23937	-	89653	38299	-	127952			
	Level 4	160	16	135	9600	6333	37235	150	N/A	21543	23937	-	89653	38299	-	127952			
	Level 3	160	16	135	9600	6333	37235	150	N/A	21543	23937	-	89653	38299	-	127952			
	Level 2	160	18	135	10800	6333	41889	150	N/A	21543	23937	-	96678	38299	-	134977			
5E	Lower Roof	258	6	146	-	11115	31052	30	N/A	37626	-	7731	95751	-	3866	99617	805	37.99	39.39
	Level 6	258	18	135	10800	11115	43990	80	73	34791	18776	-	120836	30041	-	150877			
	Level 5	258	16	135	9600	11115	41403	80	57	34791	14786	-	116290	23658	-	139948			
	Level 4	258	16	135	9600	11115	41403	80	51	34791	13019	-	116290	20830	-	137120			
	Level 3	258	16	135	9600	11115	41403	80	46	34791	11965	-	116290	19144	-	135434			
	Level 2	258	18	135	10800	11115	46578	80	44	34791	11246	-	123941	17994	-	141934			
5C	Lower Roof	177	6	146	-	5425	31052	30	N/A	25906	-	5323	74860	-	2662	77521	785	22.93	1.385
	Level 6	177	18	135	10800	5425	43990	150	N/A	23954	26616	-	101003	42585	-	143589			
	Level 5	177	16	135	9600	5425	41403	150	N/A	23954	26616	-	96458	42585	-	139044			
	Level 4	177	16	135	9600	5425	41403	150	N/A	23954	26616	-	96458	42585	-	139044			
	Level 3	177	16	135	9600	5425	41403	150	N/A	23954	26616	-	96458	42585	-	139044			
	Level 2	177	18	135	10800	5425	46578	150	N/A	23954	26616	-	104109	42585	-	146694			
6E	Lower Roof	369	6	146	-	10208	32154	30	N/A	53929	-	11081	115549	-	5541	121090	962	102.3	21.04
	Level 6	369	18	135	10800	10208	45552	80	64	49866	29550	-	139711	47280	-	186990			
	Level 5	369	16	135	9600	10208	42873	80	51	49866	18919	-	135055	30270	-	165325			
	Level 4	369	16	135	9600	10208	42873	80	45	49866	16803	-	135055	26885	-	161940			
	Level 3	369	16	135	9600	10208	42873	80	42	49866	15541	-	135055	24866	-	159921			
	Level 2	369	18	135	10800	10208	48232	80	40	49866	14681	-	142926	23489	-	166415			
6D	Lower Roof	739	-	146	-	-	-	150	N/A	107857	-	110812	129429	-	55406	184835	1730	32.05	41.88
	Level 6	739	18	135	10800	-	-	150	N/A	99731	110812	-	132637	177300	-	309937			
	Level 5	739	16	135	9600	-	-	150	N/A	99731	110812	-	131197	177300	-	308497			
	Level 4	739	16	135	9600	-	-	150	N/A	99731	110812	-	131197	177300	-	308497			
	Level 3	739	16	135	9600	-	-	150	N/A	99731	110812	-	131197	177300	-	308497			
	Level 2	739	18	135	10800	-	-	150	N/A	99731	110812	-	132637	177300	-	309937			
6C	Lower Roof	369	6	146	-	16690	31052	30	N/A	53929	-	11081	122005	-	5541	127546	1267	49.55	31.08
	Level 6	369	18	135	10800	14641	43990	150	N/A	49866	55406	-	143156	88650	-	231805			
	Level 5	369	16	135	9600	13046	41403	150	N/A	49866	55406	-	136697	88650	-	225347			
	Level 4	369	16	135	9600	9994	41403	150	N/A	49866	55406	-	133035	88650	-	221685			
	Level 3	369	16	135	9600	9858	41403	150	N/A	49866	55406	-	132871	88650	-	221521			
	Level 2	369	18	135	10800	18057	46578	150	N/A	49866	55406	-	150360	88650	-	239010			
6.7A	Lower Roof	92	6	146	-	-	-	30	N/A	13378	-	2749	16053	-	1374	17428	243	3.112	2.968
	Level 6	92	18	135	10800	2955	-	100	N/A	12370	9163	-	31350	14660	-	46010			
	Level 5	92	16	135	9600	2955	-	100	N/A	12370	9163	-	29910	14660	-	44570			
	Level 4	92	16	135	9600	2955	-	100	N/A	12370	9163	-	29910	14660	-	44570			
	Level 3	92	16	135	9600	2955	-	100	N/A	12370	9163	-	29910	14660	-	44570			
	Level 2	92	18	135	10800	2955	-	100	N/A	12370	9163	-	31350	14660	-	46010			
7E	Lower Roof	333	6	146	-	4783	29029	30	N/A	48687	-	10004	98998	-	5002	104000	838	77.61	33.19
	Level 6	333	18	135	10800	4783	41124	80	66	45018	22164	-	122070	35463	-	157534			
	Level 5	333	16	135	9600	4783	38705	80	53	45018	17626	-	117727	28202	-	145929			
	Level 4	333	16	135	9600	4783	38705	80	47	45018	15615	-	117727	24985	-	142712			
	Level 3	333	16	135	9600	4783	38705	80	43	45018	14417	-	117727	23067	-	140795			
	Level 2	333	18	135	10800	4783	43543	80	41	45018	13599	-	124973	21758	-	146732			
7D	Lower Roof	667	6	146	-	-	-	150	N/A	97373	-	100041	116848	-	50020	166868	956	21.79	41.07
	Level 6	667	18	135	10800	-	-	80	43	90037	28834	-	121004	46134	-	167138			
	Level 5	667	16	135	9600	-	-	80	36	90037	24295	-	119564	38873	-	158437			
	Level 4	667	16	135	9600	-	-	80	33	90037	22285	-	119564	35656	-	155220			
	Level 3	667	16	135	9600	-	-	80	32	90037	21086	-	119564	33738	-	153302			
	Level 2	667	18	135	10800	-	-	80	32	90037	21342	-	121004	34147	-	155151			
7C	Lower Roof	667	6	146	-	6833	-	150	N/A	97373	-	100041	125047	-	50020	175067	1244	19.76	25.21
	Level 6	667	18	135	10800	6833	-	80	43	90037	53355	-	129203	85368	-	214571			
	Level 5	667	16	135	9600	6833	-	80	36	90037	53355	-	127763	85368	-	213131			
	Level 4	667	16	135	9600	6833	-	80	33	90037	53355	-	127763	85368	-	213131			
	Level 3	667	16	135	9600	6833	-	80	32	90037	53355	-	127763	85368	-	213131			
	Level 2	667	18	135	10800	6833	-	80	32	90037	53355	-	129203	85368	-	214571			
8D	Lower Roof	389	6	146	-	-	-	150	N/A	56770	-	58325	68124	-	29163	97287	596	11.01	15.61
	Level 6	389	18	135	10800	-	-	80	50	52493	19608	-	75951	31373	-	107324			
	Level 5	389	16	135	9600	-	-	80	42	52493	16143	-	74511	25828	-	100340			
	Level 4	389	16	135	9600	-	-	80	38	52493	14608	-	74511	23372	-	97883			
	Level 3	389	16	135	9600	-	-	80	35	52493	13692	-	74511	21908	-	96419			
	Level 2	389	18	135	10800	-	-	80	34	52493	13068	-	75951	20909	-	96860			
8C	Lower Roof	401	6	146	-	4433	6863	150	N/A	58551	-	60156	83817	-	30078	113895	699	17.85	37.2
	Level 6	401	18	135	10800	4433	9723	80	50	54140	20036	-	94915	32058	-	126973			
	Level 5	401	16	135	9600	4433	9151	80	35	54140	14029	-	92789	22446	-	115234			
	Level 4	401	16	135	9600	4433	9151	80	32	54140	12833	-	92789	20533	-	113322			
	Level 3	401	16	135	9600	4433	9151	80	32	54140	12833	-	92789	20533	-	113322			
	Level 2	401	18	135	10800	4433	10295	80	32	54140	12833	-	95601	20533	-	116135			
8B	Lower Roof	160	6	146	-	8866	9119	150	N/A	23419	-	24060	49684	-	12030	61714	484	35.84	57.86
	Level 6	160	18	135	10800	8866	12918	80	N/A	21654	12832	-	65086	20531	-	85617			
	Level 5	160	16	135	9600	8866	12158	80	N/A	21654	12832	-	62734	20531	-	83265			
	Level 4	160	16	135	9600	8866	12158	80	N/A	21654	12832	-	62734	20531	-	83265			
	Level 3	160	16	135	9600	8866	12158	80	N/A	21654	12832	-	62734	20531	-	83265			
	Level 2	160	18	135	10800	8866	13678	80	N/A	21654	12832	-	65998	20531	-	86529			
9D	Lower Roof	130	6	146	-	-	9119	30	N/A	18928	-	3889	33656	-	1945	35601	355	1.703	10.53
	Level 6	130	18	135	10800	-	12918	80	N/A	17502	10372	-	49465	16595	-	66059			
	Level 5	130	16	135	9600	-	8359	80	N/A	17502	10372	-	42553	16595	-	59148			
	Level 4	130	16	135	9600	-	12918	80	N/A	17502	10372	-	48025	16595	-	64619			
	Level 3	130	16	135	9600	-	12158	80	N/A	17502	10372	-	47113	16595	-	63707			
	Level 2	130	18	135	10800	-	12918	80	N/A	17502	10372	-	49465	16595	-	66059			
9C	Lower Roof	80	6	146	-	-	6863	30	N/A	11714	-	2407	22293	-	1203	23496	257	2.041	6.296
	Level 6	80	18	135	10800	-	9723	80	N/A	10831	6419	-	37625	10270	-	47895			
	Level 5	80	16	135	9600	-	9151	80	N/A	10831	6419	-	35499	10270	-	45769			
	Level 4	80	16	135	9600	-	9151	80	N/A	10831	6419	-	35499	10270	-	45769			
	Level 3	80	16	135	9600	-	9151	80	N/A	10831	6419	-	35499	10270	-	45769			
	Level 2	80	18	135	10800	-	10295	80	N/A	10831	6419	-	38312	10270	-	48582			

Figure F1: Column Loads

SP Column Output: Column 3D



24 x 24 in

Code: ACI 318-11

Units: English

Run axis: Biaxial

Run option: Design

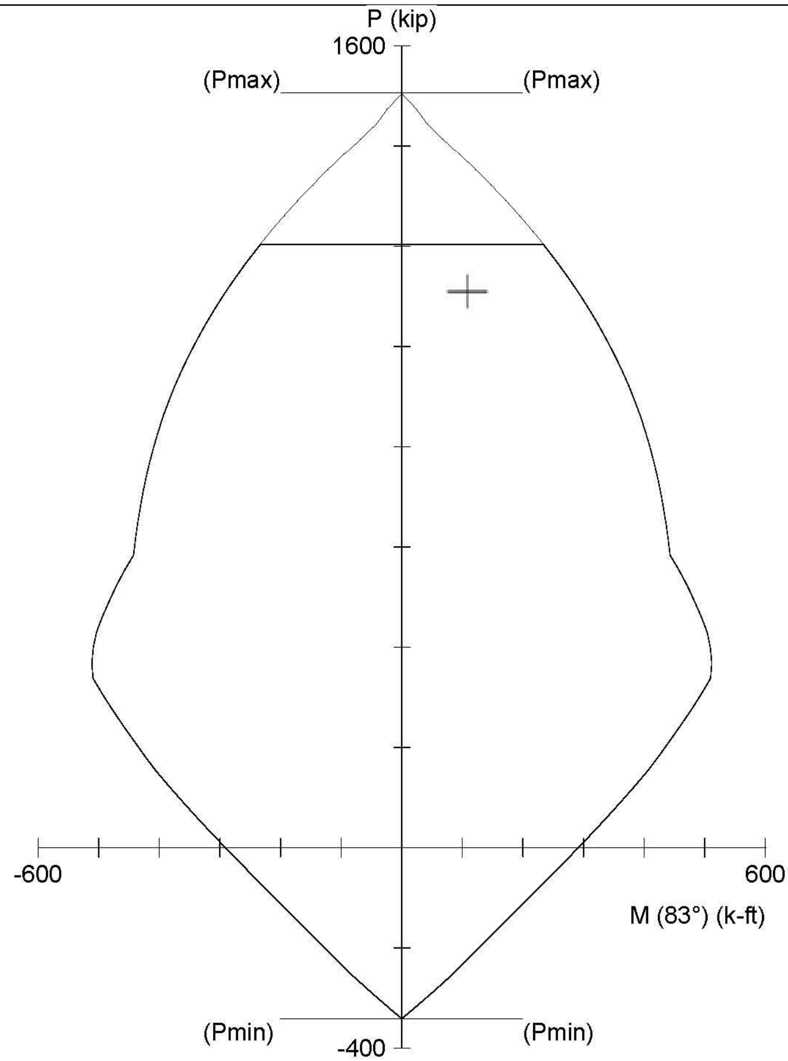
Slenderness: Not considered

Column type: Structural

Bars: ASTM A615

Date: 04/02/14

Time: 20:46:39



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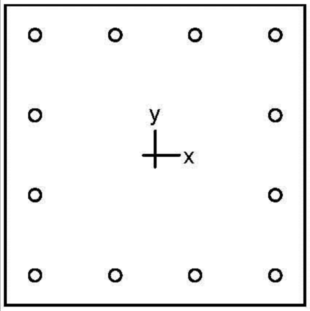
File: E:\THESIS\Spring\Columns\3D\SP Column - 3D.col

Project: UVA Library

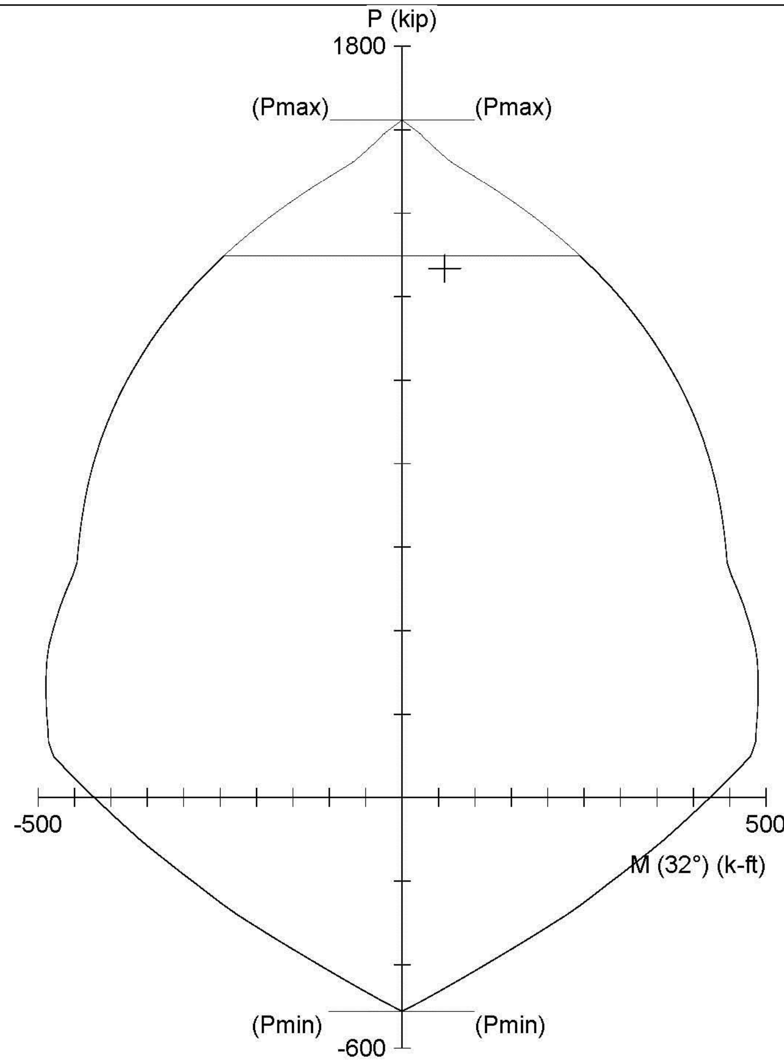
Column: 3D		Engineer: MAC	
f'c = 4 ksi	fy = 60 ksi	Ag = 576 in^2	8 #8 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 6.32 in^2	rho = 1.10%
fc = 3.4 ksi		Xo = 0.00 in	Ix = 27648 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27648 in^4
Beta1 = 0.85		Min clear spacing = 8.62 in	Clear cover = 1.87 in
Confinement: Tied			
phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65			

```
STRUCTUREPOINT - spColumn v4.81 (TM)                                                          Page   2
Licensed to: Penn State University Park. License ID: 59919-1033951-4-22545-2CF68              04/02/14
E:\THESIS\Spring\Columns\3D\SP Column - 3D.col                                                08:43 PM

General Information:
====================
  File Name: E:\THESIS\Spring\Columns\3D\SP Column - 3D.col
  Project:  UVA Library
  Column:   3D                           Engineer: MAC
  Code:     ACI 318-11                   Units: English

  Run Option: Design                     Slenderness: Not considered
  Run Axis:   Biaxial                    Column Type: Structural

Material Properties:
====================
  f'c   = 4 ksi                          fy   = 60 ksi
  Ec    = 3605 ksi                       Es   = 29000 ksi
  Ultimate strain = 0.003 in/in
  Beta1 = 0.85

Section:
========
  Rectangular: Width = 24 in             Depth = 24 in

  Gross section area, Ag =  576 in^2
  Ix =  27648 in^4                       Iy =  27648 in^4
  rx =  6.9282 in                        ry =  6.9282 in
  Xo =  0 in                             Yo =  0 in

Reinforcement:
==============
  Bar Set: ASTM A615
  Size Diam (in) Area (in^2)   Size Diam (in) Area (in^2)   Size Diam (in) Area (in^2)
  ---- --------- -----------   ---- --------- -----------   ---- --------- -----------
  #  3      0.38        0.11   #  4      0.50        0.20   #  5      0.63        0.31
  #  6      0.75        0.44   #  7      0.88        0.60   #  8      1.00        0.79
  #  9      1.13        1.00   # 10      1.27        1.27   # 11      1.41        1.56
  # 14      1.69        2.25   # 18      2.26        4.00

  Bar selection: Minimum number of bars
  Asmin = 0.01 * Ag = 5.76 in^2,  Asmax = 0.08 * Ag = 46.08 in^2

  Confinement: Tied; #3 ties with #10 bars,  #4 with larger bars.
  phi(a) = 0.8,  phi(b) = 0.9,  phi(c) = 0.65

  Layout: Rectangular
  Pattern: Equal Bar Spacing  (Cover to transverse reinforcement)
  Total steel area: As = 6.32 in^2 at rho = 1.10%
  Minimum clear spacing = 8.62 in

  8 #8   Cover = 1.5 in

Factored Loads and Moments with Corresponding Capacities:
=========================================================
  Design/Required ratio PhiMn/Mu >= 1.00
                Pu         Mux         Muy      PhiMnx      PhiMny PhiMn/Mu NA depth Dt depth    eps_t    Phi
  No.          kip        k-ft        k-ft        k-ft        k-ft                in       in
  --- ----------- ----------- ----------- ----------- ----------- -------- -------- -------- -------- ------
    1     1123.00       10.18       89.77       31.87      281.00    3.130    23.52    23.93  0.00005  0.650

  *** End of output ***
```

SP Column Output: Column 6C



24 x 24 in



Code: ACI 318-11

Units: English

Run axis: Biaxial

Run option: Design

Slenderness: Not considered

Column type: Structural

Bars: ASTM A615

Date: 04/02/14

Time: 20:18:38

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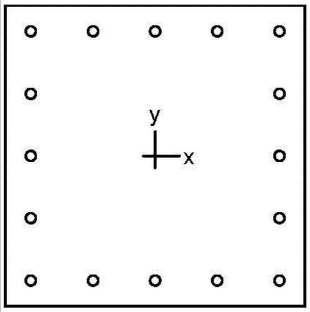
File: E:\THESIS\Spring\Columns\6C\SP Column - 6C.col

Project: UVA Library

Column: 3D		Engineer: MAC	
f'c = 4 ksi	fy = 60 ksi	Ag = 576 in^2	12 #8 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 9.48 in^2	rho = 1.65%
fc = 3.4 ksi		Xo = 0.00 in	Ix = 27648 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27648 in^4
Beta1 = 0.85		Min clear spacing = 5.41 in	Clear cover = 1.87 in
Confinement: Tied			
phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65			

```
STRUCTUREPOINT - spColumn v4.81 (TM)                                                      Page   2
Licensed to: Penn State University Park. License ID: 59919-1033951-4-22545-2CF68          04/02/14
E:\THESIS\Spring\Columns\6C\SP Column - 6C.col                                            08:17 PM

General Information:
====================
  File Name: E:\THESIS\Spring\Columns\6C\SP Column - 6C.col
  Project:  UVA Library
  Column:   3D                          Engineer: MAC
  Code:     ACI 318-11                  Units: English

  Run Option: Design                    Slenderness: Not considered
  Run Axis:   Biaxial                   Column Type: Structural

Material Properties:
====================
  f'c    = 4 ksi                        fy    = 60 ksi
  Ec     = 3605 ksi                     Es    = 29000 ksi
  Ultimate strain = 0.003 in/in
  Beta1 = 0.85

Section:
========
  Rectangular: Width = 24 in            Depth = 24 in

  Gross section area, Ag =  576 in^2
  Ix =  27648 in^4                      Iy =  27648 in^4
  rx =  6.9282 in                       ry =  6.9282 in
  Xo =  0 in                            Yo =  0 in

Reinforcement:
==============
  Bar Set: ASTM A615
  Size Diam (in) Area (in^2)   Size Diam (in) Area (in^2)   Size Diam (in) Area (in^2)
  ---- --------- -----------   ---- --------- -----------   ---- --------- -----------
  #  3      0.38        0.11   #  4      0.50        0.20   #  5      0.63        0.31
  #  6      0.75        0.44   #  7      0.88        0.60   #  8      1.00        0.79
  #  9      1.13        1.00   # 10      1.27        1.27   # 11      1.41        1.56
  # 14      1.69        2.25   # 18      2.26        4.00

  Bar selection: Minimum number of bars
  Asmin = 0.01 * Ag = 5.76 in^2,  Asmax = 0.08 * Ag = 46.08 in^2

  Confinement: Tied; #3 ties with #10 bars,  #4 with larger bars.
  phi(a) = 0.8,  phi(b) = 0.9,  phi(c) = 0.65

  Layout: Rectangular
  Pattern: Equal Bar Spacing  (Cover to transverse reinforcement)
  Total steel area: As = 9.48 in^2 at rho = 1.65%
  Minimum clear spacing = 5.41 in

  12 #8   Cover = 1.5 in

Factored Loads and Moments with Corresponding Capacities:
=========================================================
  Design/Required ratio PhiMn/Mu >= 1.00
               Pu         Mux         Muy      PhiMnx      PhiMny PhiMn/Mu NA depth Dt depth    eps_t    Phi
  No.         kip        k-ft        k-ft        k-ft        k-ft                in       in
  --- ----------- ----------- ----------- ----------- ----------- -------- -------- -------- -------- ------
    1     1267.00       49.55       31.08      222.39      139.50    4.488    28.03    29.40  0.00015  0.650

  *** End of output ***
```

SP Column Output: Column 6D



28 x 28 in

Code: ACI 318-11

Units: English

Run axis: Biaxial

Run option: Design

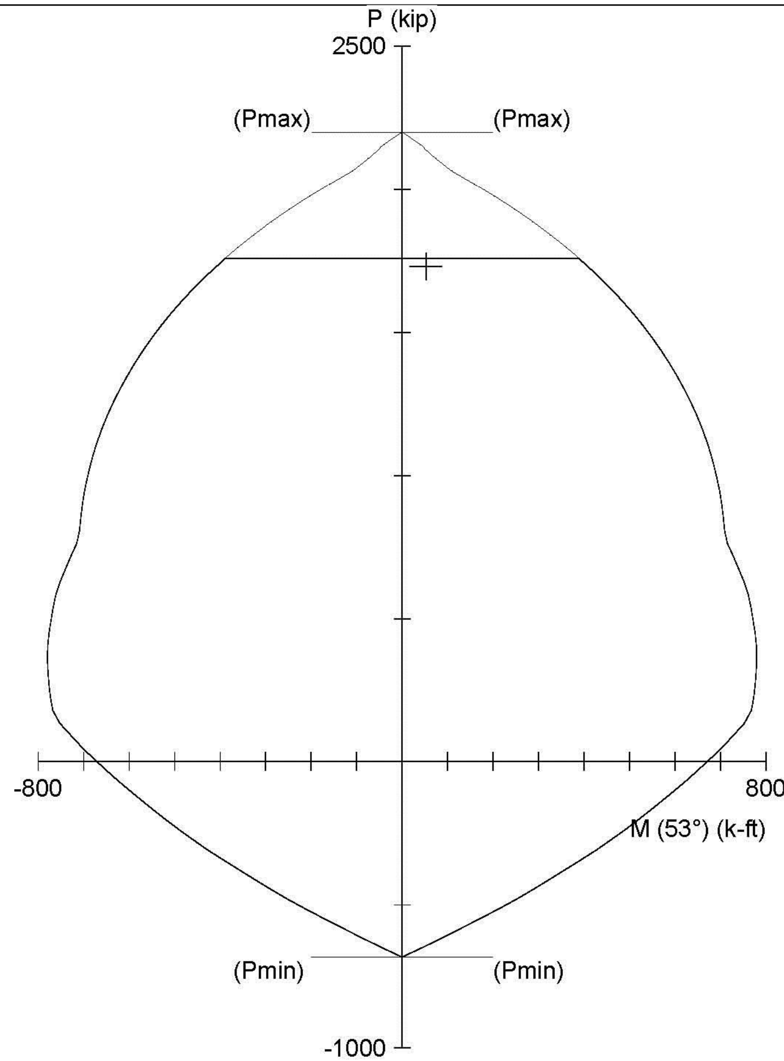
Slenderness: Not considered

Column type: Structural

Bars: ASTM A615

Date: 04/02/14

Time: 18:35:13



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File: e:\thesis\spring\columns\6d\sp column - 6d.col

Project: UVA Library

Column: 3D		Engineer: MAC	
f'c = 4 ksi	fy = 60 ksi	Ag = 784 in^2	16 #8 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 12.64 in^2	rho = 1.61%
fc = 3.4 ksi		Xo = 0.00 in	Ix = 51221.3 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 51221.3 in^4
Beta1 = 0.85		Min clear spacing = 4.81 in	Clear cover = 1.87 in
Confinement: Tied			
phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65			

STRUCTUREPOINT - spColumn v4.81 (TM)
Licensed to: Penn State University Park. License ID: 59919-1033951-4-22545-2CF68
e:\thesis\spring\columns\6d\sp column - 6d.col

General Information:
====================

File Name: e:\thesis\spring\columns\6d\sp column - 6d.col
Project: UVA Library
Column: 3D — Engineer: MAC
Code: ACI 318-11 — Units: English

Run Option: Design — Slenderness: Not considered
Run Axis: Biaxial — Column Type: Structural

Material Properties:
====================

f'c = 4 ksi — fy = 60 ksi
Ec = 3605 ksi — Es = 29000 ksi
Ultimate strain = 0.003 in/in
Beta1 = 0.85

Section:
========

Rectangular: Width = 28 in — Depth = 28 in

Gross section area, Ag = 784 in^2
Ix = 51221.3 in^4 — Iy = 51221.3 in^4
rx = 8.0829 in — ry = 8.0829 in
Xo = 0 in — Yo = 0 in

Reinforcement:
==============

Bar Set: ASTM A615

Size	Diam (in)	Area (in^2)	Size	Diam (in)	Area (in^2)	Size	Diam (in)	Area (in^2)
# 3	0.38	0.11	# 4	0.50	0.20	# 5	0.63	0.31
# 6	0.75	0.44	# 7	0.88	0.60	# 8	1.00	0.79
# 9	1.13	1.00	# 10	1.27	1.27	# 11	1.41	1.56
# 14	1.69	2.25	# 18	2.26	4.00			

Bar selection: Minimum area of steel
Asmin = 0.01 * Ag = 7.84 in^2, Asmax = 0.08 * Ag = 62.72 in^2

Confinement: Tied; #3 ties with #10 bars, #4 with larger bars.
phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65

Layout: Rectangular
Pattern: Equal Bar Spacing (Cover to transverse reinforcement)
Total steel area: As = 12.64 in^2 at rho = 1.61%
Minimum clear spacing = 4.81 in

16 #8 Cover = 1.5 in

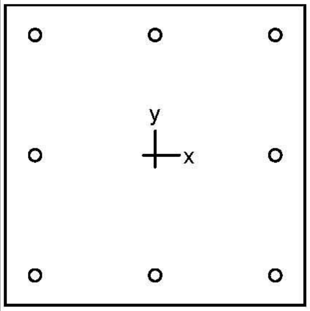
Factored Loads and Moments with Corresponding Capacities:
===

Design/Required ratio PhiMn/Mu >= 1.00

No.	Pu kip	Mux k-ft	Muy k-ft	PhiMnx k-ft	PhiMny k-ft	PhiMn/Mu	NA depth in	Dt depth in	eps_t	Phi
1	1730.00	32.05	41.88	247.97	324.03	7.737	33.43	35.60	0.00019	0.650

*** End of output ***

SP Column Output: Column 6E



24 x 24 in

Code: ACI 318-11

Units: English

Run axis: Biaxial

Run option: Design

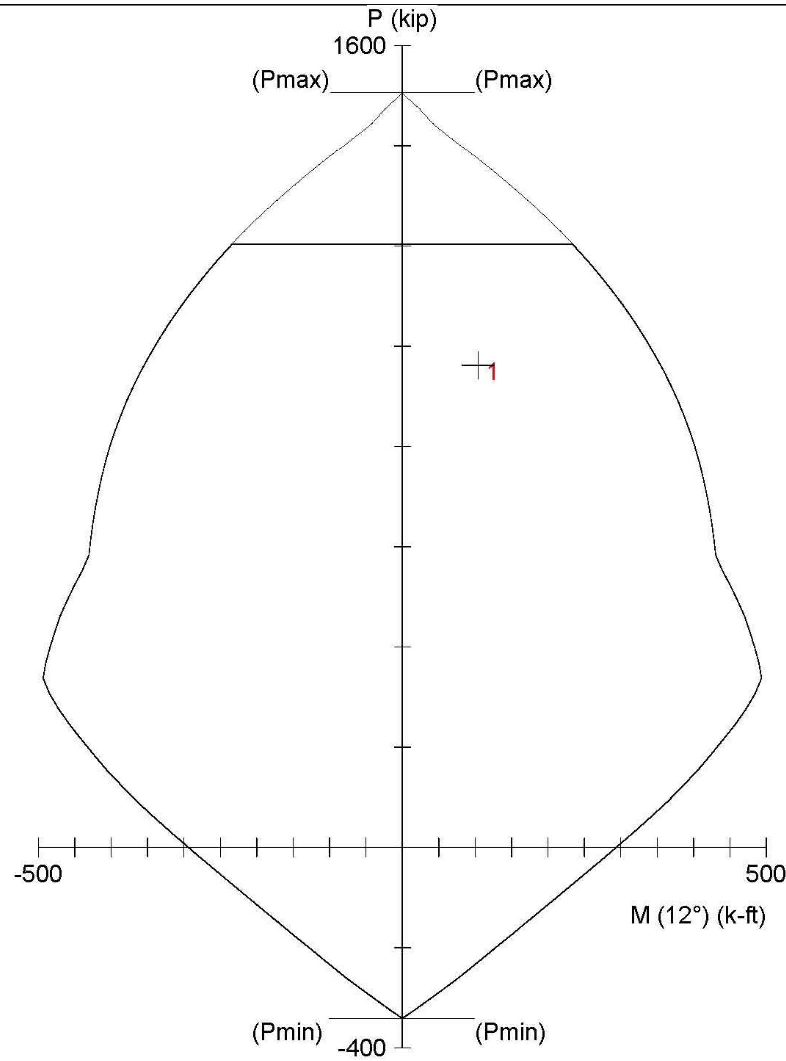
Slenderness: Not considered

Column type: Structural

Bars: ASTM A615

Date: 04/02/14

Time: 20:55:40



spColumn v4.81. Licensed to: Penn State University Park. License ID: 59919-1033951-4-22545-2CF68

File: E:\THESIS\Spring\Columns\6E\SP Column - 6E.col

Project: UVA Library

Column: 3D

Engineer: MAC

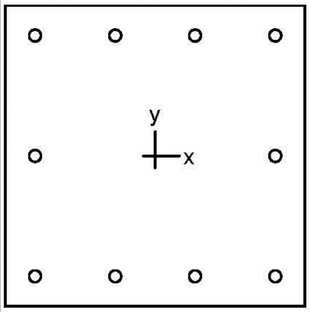
f'c = 4 ksi	fy = 60 ksi	Ag = 576 in^2	8 #8 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 6.32 in^2	rho = 1.10%
fc = 3.4 ksi		Xo = 0.00 in	Ix = 27648 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27648 in^4
Beta1 = 0.85		Min clear spacing = 8.62 in	Clear cover = 1.87 in

Confinement: Tied

phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65

```
STRUCTUREPOINT - spColumn v4.81 (TM)                                                                   Page   2
Licensed to: Penn State University Park. License ID: 59919-1033951-4-22545-2CF68                       04/02/14
E:\THESIS\Spring\Columns\6E\SP Column - 6E.col                                                         08:55 PM


General Information:
====================
  File Name: E:\THESIS\Spring\Columns\6E\SP Column - 6E.col
  Project:  UVA Library
  Column:   3D                               Engineer: MAC
  Code:     ACI 318-11                       Units: English

  Run Option: Design                         Slenderness: Not considered
  Run Axis:   Biaxial                        Column Type: Structural

Material Properties:
====================
  f'c   = 4 ksi                              fy   = 60 ksi
  Ec    = 3605 ksi                           Es   = 29000 ksi
  Ultimate strain = 0.003 in/in
  Beta1 = 0.85

Section:
========
  Rectangular: Width = 24 in                 Depth = 24 in

  Gross section area, Ag =  576 in^2
  Ix =  27648 in^4                           Iy =  27648 in^4
  rx =  6.9282 in                            ry =  6.9282 in
  Xo =  0 in                                 Yo =  0 in

Reinforcement:
==============
  Bar Set: ASTM A615
  Size Diam (in) Area (in^2)   Size Diam (in) Area (in^2)   Size Diam (in) Area (in^2)
  ---- --------- -----------   ---- --------- -----------   ---- --------- -----------
  #  3      0.38        0.11   #  4      0.50        0.20   #  5      0.63        0.31
  #  6      0.75        0.44   #  7      0.88        0.60   #  8      1.00        0.79
  #  9      1.13        1.00   # 10      1.27        1.27   # 11      1.41        1.56
  # 14      1.69        2.25   # 18      2.26        4.00

  Bar selection: Minimum number of bars
  Asmin = 0.01 * Ag = 5.76 in^2,  Asmax = 0.08 * Ag = 46.08 in^2

  Confinement: Tied; #3 ties with #10 bars,  #4 with larger bars.
  phi(a) = 0.8,  phi(b) = 0.9,  phi(c) = 0.65

  Layout: Rectangular
  Pattern: Equal Bar Spacing  (Cover to transverse reinforcement)
  Total steel area: As = 6.32 in^2 at rho = 1.10%
  Minimum clear spacing = 8.62 in

  8 #8   Cover = 1.5 in

Factored Loads and Moments with Corresponding Capacities:
=========================================================
  Design/Required ratio PhiMn/Mu >= 1.00
                   Pu         Mux         Muy      PhiMnx      PhiMny PhiMn/Mu NA depth Dt depth    eps_t    Phi
  No.             kip        k-ft        k-ft        k-ft        k-ft                in       in
  --- ----------- ----------- ----------- ----------- ----------- -------- -------- -------- -------- ------
    1      962.00      102.30       21.04      347.95       71.56    3.401    21.93    26.20  0.00058  0.650

  *** End of output ***
```

SP Column Output: Column 7C



24 x 24 in

Code: ACI 318-11

Units: English

Run axis: Biaxial

Run option: Design

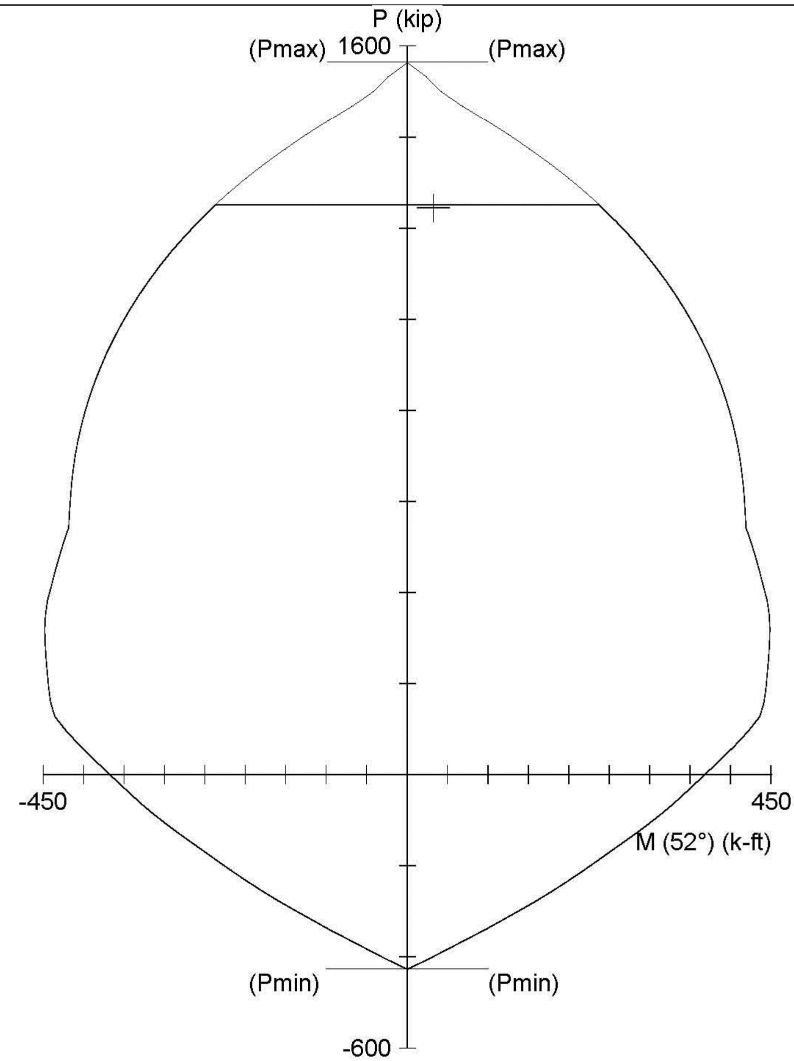
Slenderness: Not considered

Column type: Structural

Bars: ASTM A615

Date: 04/02/14

Time: 20:32:31



spColumn v4.81. Licensed to: Penn State University Park. License ID: 59919-1033951-4-22545-2CF68

File: E:\THESIS\Spring\Columns\7C\SP Column - 7C.col

Project: UVA Library

Column: 3D

Engineer: MAC

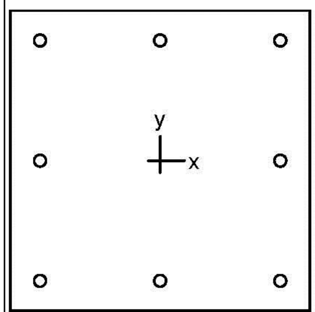
f'c = 4 ksi	fy = 60 ksi	Ag = 576 in^2	10 #8 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 7.90 in^2	rho = 1.37%
fc = 3.4 ksi		Xo = 0.00 in	Ix = 27648 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27648 in^4
Beta1 = 0.85		Min clear spacing = 5.41 in	Clear cover = 1.87 in

Confinement: Tied

phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65

```
STRUCTUREPOINT - spColumn v4.81 (TM)                                                                    Page   2
Licensed to: Penn State University Park. License ID: 59919-1033951-4-22545-2CF68                        04/02/14
E:\THESIS\Spring\Columns\7C\SP Column - 7C.col                                                          08:31 PM

General Information:
====================
  File Name: E:\THESIS\Spring\Columns\7C\SP Column - 7C.col
  Project:  UVA Library
  Column:   3D                                Engineer: MAC
  Code:     ACI 318-11                        Units: English

  Run Option: Design                          Slenderness: Not considered
  Run Axis:   Biaxial                         Column Type: Structural

Material Properties:
====================
  f'c   = 4 ksi                               fy   = 60 ksi
  Ec    = 3605 ksi                            Es   = 29000 ksi
  Ultimate strain = 0.003 in/in
  Beta1 = 0.85

Section:
========
  Rectangular: Width = 24 in                  Depth = 24 in

  Gross section area, Ag =  576 in^2
  Ix =  27648 in^4                            Iy =  27648 in^4
  rx =  6.9282 in                             ry =  6.9282 in
  Xo =  0 in                                  Yo =  0 in

Reinforcement:
==============
  Bar Set: ASTM A615
  Size Diam (in) Area (in^2)   Size Diam (in) Area (in^2)   Size Diam (in) Area (in^2)
  ---- --------- -----------   ---- --------- -----------   ---- --------- -----------
  #  3      0.38        0.11   #  4      0.50        0.20   #  5      0.63        0.31
  #  6      0.75        0.44   #  7      0.88        0.60   #  8      1.00        0.79
  #  9      1.13        1.00   # 10      1.27        1.27   # 11      1.41        1.56
  # 14      1.69        2.25   # 18      2.26        4.00

  Bar selection: Minimum number of bars
  Asmin = 0.01 * Ag = 5.76 in^2,  Asmax = 0.08 * Ag = 46.08 in^2

  Confinement: Tied; #3 ties with #10 bars,  #4 with larger bars.
  phi(a) = 0.8,  phi(b) = 0.9,  phi(c) = 0.65

  Layout: Rectangular
  Pattern: Equal Bar Spacing  (Cover to transverse reinforcement)
  Total steel area: As = 7.90 in^2 at rho = 1.37%
  Minimum clear spacing = 5.41 in

  10 #8   Cover = 1.5 in

Factored Loads and Moments with Corresponding Capacities:
=========================================================
  Design/Required ratio PhiMn/Mu >= 1.00
                  Pu         Mux         Muy      PhiMnx      PhiMny PhiMn/Mu NA depth Dt depth    eps_t    Phi
  No.            kip        k-ft        k-ft        k-ft        k-ft                in       in
  --- ----------- ----------- ----------- ----------- ----------- -------- -------- -------- -------- ------
    1     1244.00       19.76       25.21      148.75      189.78    7.528    28.54    29.86  0.00014  0.650

  *** End of output ***
```

SP Column Output: Column 7E



24 x 24 in

Code: ACI 318-11

Units: English

Run axis: Biaxial

Run option: Design

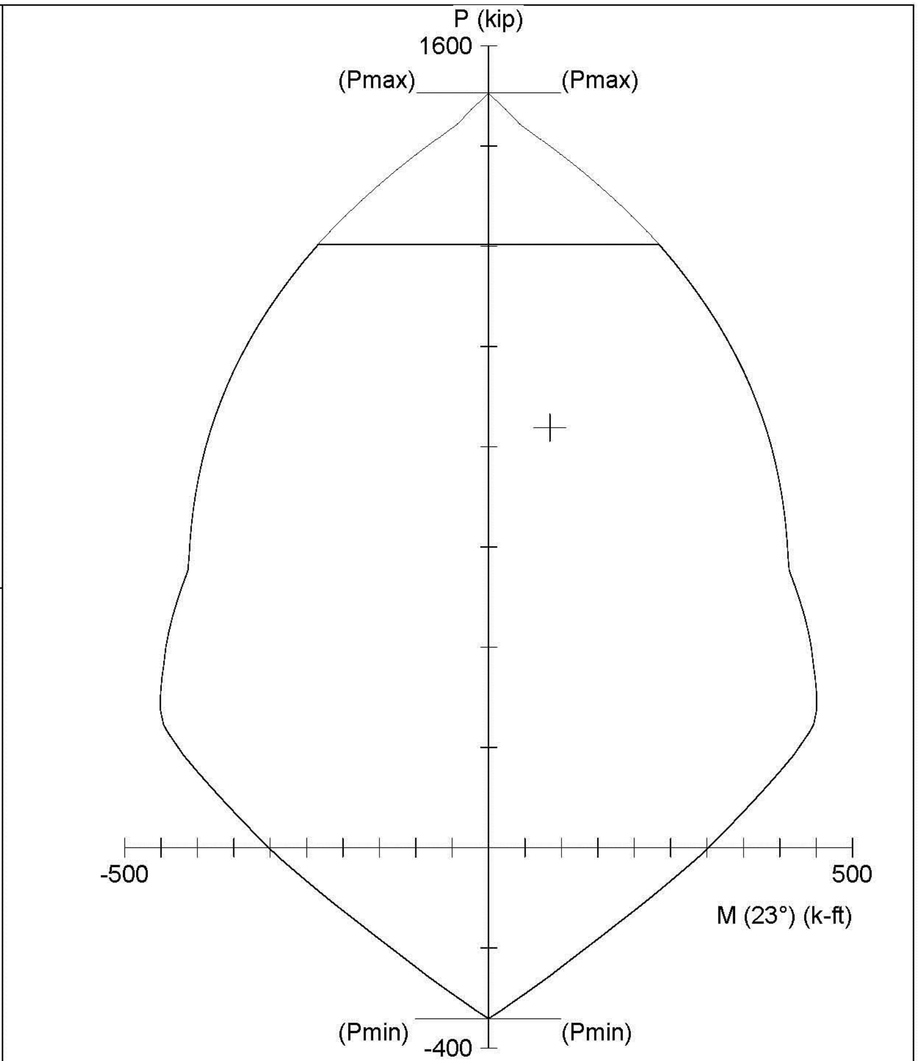
Slenderness: Not considered

Column type: Structural

Bars: ASTM A615

Date: 04/02/14

Time: 20:25:05



spColumn v4.81. Licensed to: Penn State University Park. License ID: 59919-1033951-4-22545-2CF68

File: E:\THESIS\Spring\Columns\7E\SP Column - 7E.col

Project: UVA Library

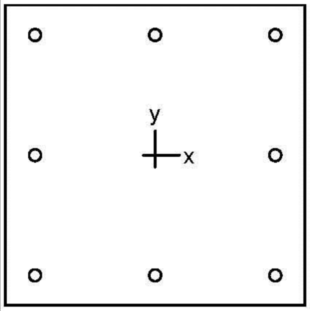
Column: 3D		Engineer: MAC	
f'c = 4 ksi	fy = 60 ksi	Ag = 576 in^2	8 #8 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 6.32 in^2	rho = 1.10%
fc = 3.4 ksi		Xo = 0.00 in	Ix = 27648 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27648 in^4
Beta1 = 0.85		Min clear spacing = 8.62 in	Clear cover = 1.87 in

Confinement: Tied

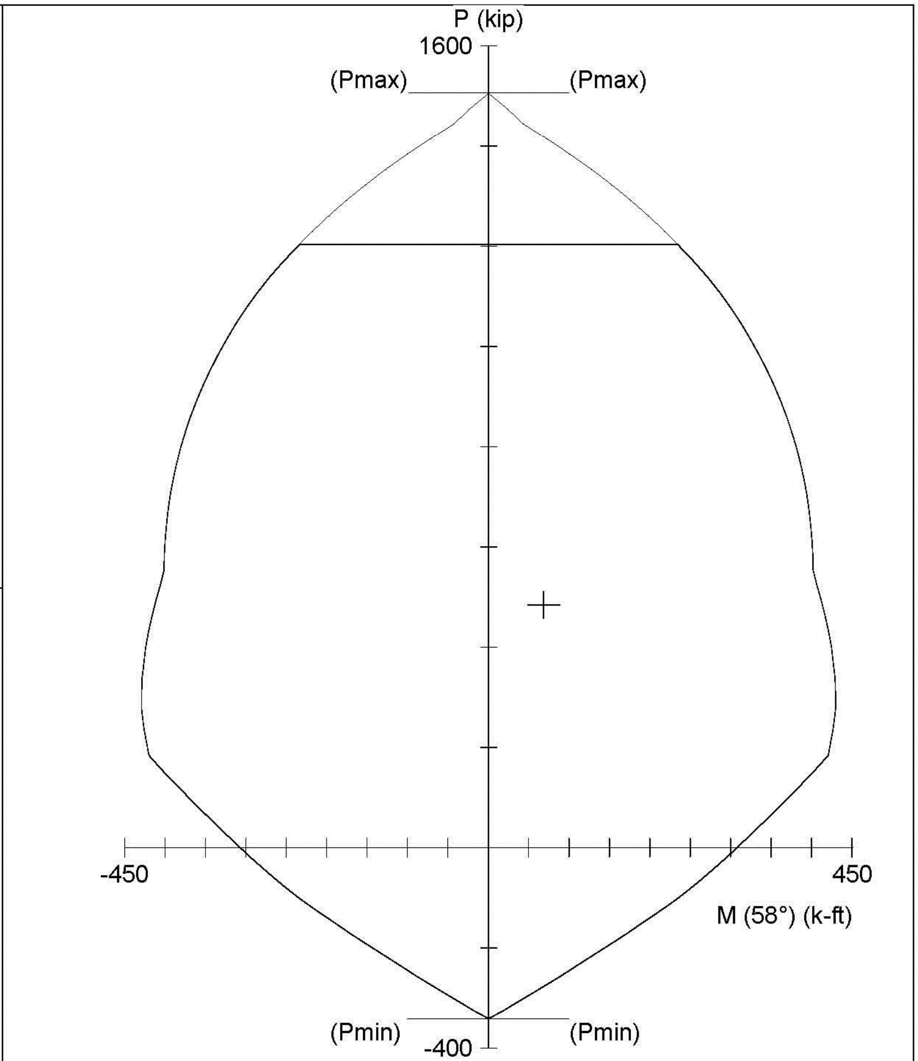
phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65

```
STRUCTUREPOINT - spColumn v4.81 (TM)                                                                Page   2
Licensed to: Penn State University Park. License ID: 59919-1033951-4-22545-2CF68                   04/02/14
E:\THESIS\Spring\Columns\7E\SP Column - 7E.col                                                      08:24 PM


General Information:
====================
  File Name: E:\THESIS\Spring\Columns\7E\SP Column - 7E.col
  Project:  UVA Library
  Column:   3D                              Engineer: MAC
  Code:     ACI 318-11                      Units: English

  Run Option: Design                        Slenderness: Not considered
  Run Axis:   Biaxial                       Column Type: Structural

Material Properties:
====================
  f'c    = 4 ksi                            fy    = 60 ksi
  Ec     = 3605 ksi                         Es    = 29000 ksi
  Ultimate strain = 0.003 in/in
  Beta1 = 0.85

Section:
========
  Rectangular: Width = 24 in                Depth = 24 in

  Gross section area, Ag =  576 in^2
  Ix =  27648 in^4                          Iy =  27648 in^4
  rx =  6.9282 in                           ry =  6.9282 in
  Xo =  0 in                                Yo =  0 in

Reinforcement:
==============
  Bar Set: ASTM A615
  Size Diam (in) Area (in^2)   Size Diam (in) Area (in^2)   Size Diam (in) Area (in^2)
  ---- --------- -----------   ---- --------- -----------   ---- --------- -----------
  #  3      0.38        0.11   #  4      0.50        0.20   #  5      0.63        0.31
  #  6      0.75        0.44   #  7      0.88        0.60   #  8      1.00        0.79
  #  9      1.13        1.00   # 10      1.27        1.27   # 11      1.41        1.56
  # 14      1.69        2.25   # 18      2.26        4.00

  Bar selection: Minimum number of bars
  Asmin = 0.01 * Ag = 5.76 in^2,  Asmax = 0.08 * Ag = 46.08 in^2

  Confinement: Tied; #3 ties with #10 bars,  #4 with larger bars.
  phi(a) = 0.8,  phi(b) = 0.9,  phi(c) = 0.65

  Layout: Rectangular
  Pattern: Equal Bar Spacing  (Cover to transverse reinforcement)
  Total steel area: As = 6.32 in^2 at rho = 1.10%
  Minimum clear spacing = 8.62 in

  8 #8   Cover = 1.5 in

Factored Loads and Moments with Corresponding Capacities:
=========================================================
  Design/Required ratio PhiMn/Mu >= 1.00
                 Pu         Mux         Muy      PhiMnx      PhiMny PhiMn/Mu NA depth Dt depth    eps_t    Phi
  No.           kip        k-ft        k-ft        k-ft        k-ft               in       in
  --- ----------- ----------- ----------- ----------- ----------- -------- -------- -------- -------- ------
    1      838.00       77.61       33.19      350.02      149.68    4.510    21.50    29.13  0.00106  0.650

  *** End of output ***
```

SP Column Output: Column 8B



24 x 24 in



Code: ACI 318-11

Units: English

Run axis: Biaxial

Run option: Design

Slenderness: Not considered

Column type: Structural

Bars: ASTM A615

Date: 04/02/14

Time: 20:28:53

spColumn v4.81. Licensed to: Penn State University Park. License ID: 59919-1033951-4-22545-2CF68

File: E:\THESIS\Spring\Columns\8B\SP Column - 8B.col

Project: UVA Library

Column: 3D		Engineer: MAC	
f'c = 4 ksi	fy = 60 ksi	Ag = 576 in^2	8 #8 bars
Ec = 3605 ksi	Es = 29000 ksi	As = 6.32 in^2	rho = 1.10%
fc = 3.4 ksi		Xo = 0.00 in	Ix = 27648 in^4
e_u = 0.003 in/in		Yo = 0.00 in	Iy = 27648 in^4
Beta1 = 0.85		Min clear spacing = 8.62 in	Clear cover = 1.87 in

Confinement: Tied

phi(a) = 0.8, phi(b) = 0.9, phi(c) = 0.65

```
STRUCTUREPOINT - spColumn v4.81 (TM)                                                                 Page   2
Licensed to: Penn State University Park. License ID: 59919-1033951-4-22545-2CF68                     04/02/14
E:\THESIS\Spring\Columns\8B\SP Column - 8B.col                                                       08:28 PM


General Information:
====================
  File Name: E:\THESIS\Spring\Columns\8B\SP Column - 8B.col
  Project:  UVA Library
  Column:   3D                                Engineer: MAC
  Code:     ACI 318-11                        Units: English

  Run Option: Design                          Slenderness: Not considered
  Run Axis:   Biaxial                         Column Type: Structural

Material Properties:
====================
  f'c   = 4 ksi                               fy   = 60 ksi
  Ec    = 3605 ksi                            Es   = 29000 ksi
  Ultimate strain = 0.003 in/in
  Beta1 = 0.85

Section:
========
  Rectangular: Width = 24 in                  Depth = 24 in

  Gross section area, Ag =  576 in^2
  Ix =  27648 in^4                            Iy =  27648 in^4
  rx =  6.9282 in                             ry =  6.9282 in
  Xo =  0 in                                  Yo =  0 in

Reinforcement:
==============
  Bar Set: ASTM A615
  Size Diam (in) Area (in^2)   Size Diam (in) Area (in^2)   Size Diam (in) Area (in^2)
  ---- --------- -----------   ---- --------- -----------   ---- --------- -----------
  #  3      0.38        0.11   #  4      0.50        0.20   #  5      0.63        0.31
  #  6      0.75        0.44   #  7      0.88        0.60   #  8      1.00        0.79
  #  9      1.13        1.00   # 10      1.27        1.27   # 11      1.41        1.56
  # 14      1.69        2.25   # 18      2.26        4.00

  Bar selection: Minimum number of bars
  Asmin = 0.01 * Ag = 5.76 in^2,  Asmax = 0.08 * Ag = 46.08 in^2

  Confinement: Tied; #3 ties with #10 bars,  #4 with larger bars.
  phi(a) = 0.8,  phi(b) = 0.9,  phi(c) = 0.65

  Layout: Rectangular
  Pattern: Equal Bar Spacing  (Cover to transverse reinforcement)
  Total steel area: As = 6.32 in^2 at rho = 1.10%
  Minimum clear spacing = 8.62 in

  8 #8   Cover = 1.5 in

Factored Loads and Moments with Corresponding Capacities:
=========================================================
  Design/Required ratio PhiMn/Mu >= 1.00
                 Pu         Mux         Muy      PhiMnx      PhiMny PhiMn/Mu NA depth Dt depth    eps_t    Phi
  No.           kip        k-ft        k-ft        k-ft        k-ft               in       in
  --- ----------- ----------- ----------- ----------- ----------- -------- -------- -------- -------- ------
    1      484.00       35.84       57.86      217.56      351.22    6.070    16.51    29.97  0.00245  0.682

  *** End of output ***
```

Appendix G: PT Floor Design

Below are images of the latitude design spans numbered and the floor plan with the grid shown. The design spans and column line locations are referenced in the following tables, so these images are provided for reference.

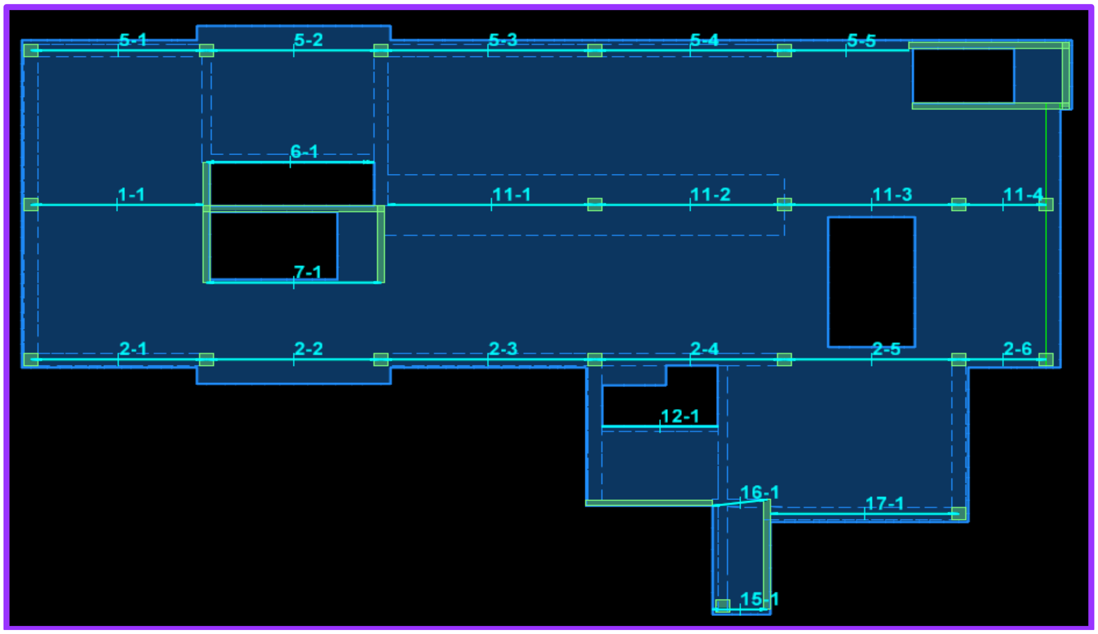


Figure G1: Latitude Span Segments

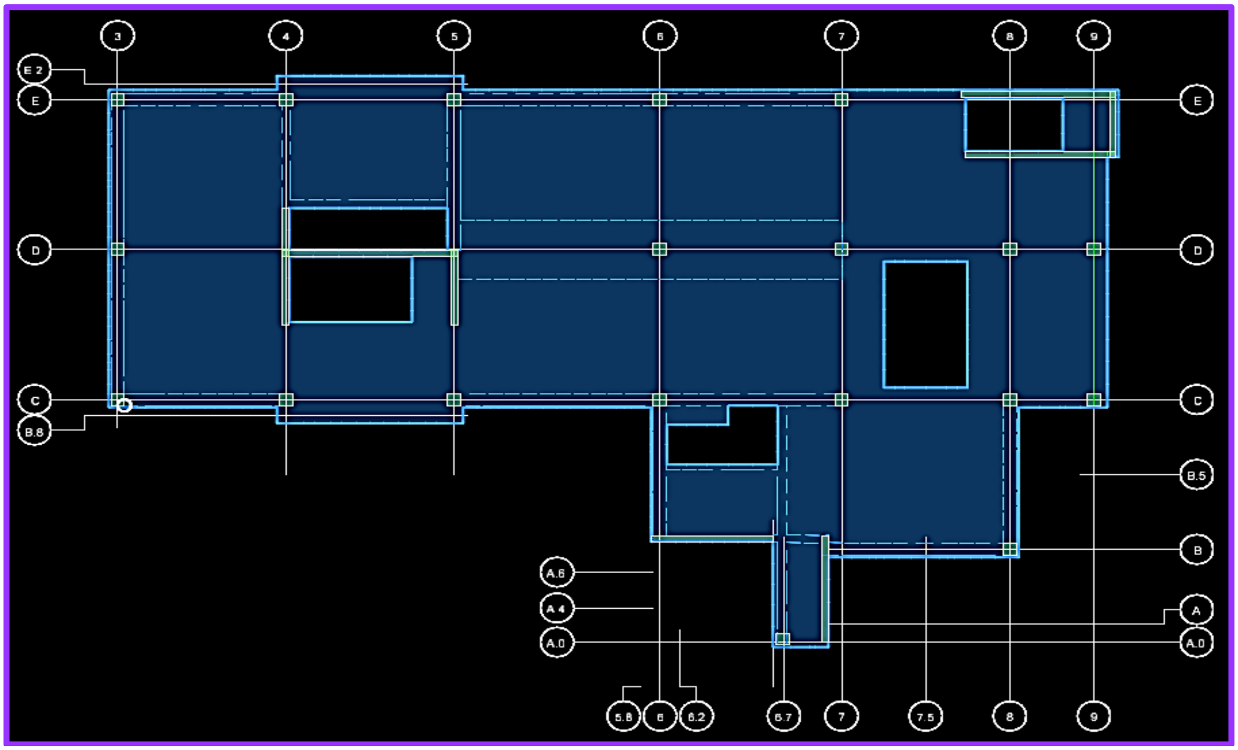


Figure G2: Floor Plan with Grid Lines

Appendix G.1: Initial Tendon Elevations

Note: Elevations measured from soffit.

Latitude Direction		
Member	Location	Elevation of Tendon (in)
30" Beam	High	29
	Middle	26
	Low	23
24" Beam	High	23
	Middle	20
	Low	17
Slab	High	7
	Middle	4
	Low	1

Table G1: Elevation of Tendons – Latitude Direction

Longitude Direction		
Member	Location	Elevation of Tendon (in)
30" Beam	High	28.5
	Middle	26
	Low	23.5
24" Beam	High	22.5
	Middle	20
	Low	17.5
Slab	High	6.5
	Middle	4
	Low	1.5

Table G2: Elevation of Tendons – Longitude Direction

Appendix G.2: Initial Number of Tendons (Banded Direction)

Span Number	Slab Depth (in)	Strip Width (FT)	Strip Width (in)	Strip Area (in^2)	Initial Force (K)	Number of Tendons
5-1	8	14.3	172	1373	172	7
5-2	8	14.3	172	1373	172	7
5-3	8	14.3	172	1373	172	7
5-4	8	14.3	172	1373	172	7
5-5	8	14.3	172	1373	172	7
1-1	8	25.3	304	2429	304	12
11-1	8	24.3	292	2333	292	11
11-2	8	25.3	304	2429	304	12
11-3	8	25.3	304	2429	304	12
11-4	8	20.7	248	1987	248	10
2-1	8	14	168	1344	168	7
2-2	8	14.3	172	1373	172	7
2-3	8	14	168	1344	168	7
2-4	8	25.3	304	2429	304	12
2-5	8	25.3	304	2429	304	12
2-6	8	14	168	1344	168	7
17-1	8	16	192	1536	192	8
16-1	8	14.1	169	1354	169	7
6-1	8	9.2	110	883	110	5
7-1	8	6.8	82	653	82	4

Table G3: Initial Number of Tendons – Banded Direction

Appendix G.3: Final Balancing of Tendons

Latitude Tendons

Span Number	Slab Depth (in)	Strip Width (FT)	Strip Area in (ft^2)	Weight in k/Ft of Strip	Upper Limit	Lower Limit	Balancing Load Given by Concept	Pass/Fail	Adjusted Tendon Elevation	New Balanced Load
5-1	8	14.3	10	1.43	1.788	0.715	1.978	FAIL	17.75	1.653
5-2	8	14.3	10	1.43	1.788	0.715	2.045	FAIL	2.5	1.771
5-3	8	14.3	10	1.43	1.788	0.715	0.780	PASS		
5-4 (1)	8	14.3	10	1.43	1.788	0.715	0.430	PASS		
5-4 (2)							0.469			
5-5 (1)	8	14.3	10	1.43	1.788	0.715	0.693	PASS		
5-5 (2)							1.003			
1-1 (1)	8	25.3	17	2.53	3.163	1.265	2.279	PASS		
1-1 (2)							0.306			
6-1	8	10.5	7	1.05	1.313	0.525	3.517	FAIL	5	1.223
11-1 (1)	8	24.3	16	2.43	3.038	1.215	2.253	PASS		
11-1 (2)							0.632			
11-2	8	25.3	17	2.53	3.163	1.265	3.728	FAIL	6	3.107
11-3	8	25.3	17	2.53	3.163	1.265	2.003	PASS		
11-4	8	20.7	14	2.07	2.588	1.035	4.853	FAIL	3.25	2.525
2-1	8	7	5	0.7	0.875	0.350	1.978	FAIL	25.8	0.7866
2-1 M	8	14	9	1.4	1.750	0.700	0.876	PASS		
2-2	8	14.3	10	1.43	1.788	0.715	2.103	FAIL	2.5	1.779
2-2 M	8	14.3	10	1.43	1.788	0.715	1.168	PASS		
2-3	8	14	9	1.4	1.750	0.700	0.747	PASS		
							0.780			
2-4	8	25.3	17	2.53	3.163	1.265	0.978	PASS		
							1.004			
2-5	8	25.3	17	2.53	3.163	1.265	1.335	PASS		
2-6	8	14	9	1.4	1.750	0.700	2.921	FAIL	3	1.683
Span 6-7 Along B	8	6.8	5	0.68	0.850	0.340	0.614	PASS		
17-1	8	16	11	1.6	2.000	0.800	0.878	PASS		

Table G4: Balancing of Latitude Tendons

Longitude Tendons

Vertical Column Lines	Horizontal Column Lines	Slab Depth (in)	Strip Width (FT)	Strip Area in (ft^2)	Weight in k/Ft of Strip	Upper Limit	Lower Limit	Balancing Load Given by Concept	Pass/Fail	Adjusted Tendon Elevation	New Balanced Load
3-4	E-D	8	4.22	3	0.42	0.528	0.211	0.2851	PASS		
	D-C	8	4.22	3	0.42	0.528	0.211	0.2851	PASS		
4-5	E.2-E	8	4.22	3	0.42	0.528	0.211	1.519	FAIL	4.75	0.4556
	E-D	8	4.22	3	0.42	0.528	0.211	0.3113	PASS		
	D-C	8	4.22	3	0.42	0.528	0.211	0.8402	FAIL	3	0.3081
	C-B.8	8	4.22	3	0.42	0.528	0.211	1.519	FAIL	4.75	0.4556
5-6	E-D	8	4.43	3	0.44	0.554	0.222	0.2851	PASS		
	D-C	8	4.43	3	0.44	0.554	0.222	0.1939	PASS		
6-7	E-D	8	3.9	3	0.39	0.488	0.195	0.3801	PASS		
	D-C (Discontinuous)	8	3.9	3	0.39	0.488	0.195	0.3957	PASS		
	D-C (Continuous)	8	3.9	3	0.39	0.488	0.195	0.459	PASS		
	C-B (Discontinuous - Short)	8	3.9	3	0.39	0.488	0.195	2.674	FAIL	26.25	0.2674
	C-B (Discontinuous - Long)	8	3.9	3	0.39	0.488	0.195	2.036	FAIL	3.5	0.2327
	C-B (Continuous - Short)	8	3.9	3	0.39	0.488	0.195	0.4768	PASS		
	C-B (Continuous - Long)	8	3.9	3	0.39	0.488	0.195	0.6383	FAIL	2.75	0.4787
	B-A	8	3.9	3	0.39	0.488	0.195	0.8251	FAIL	3.25	0.4401
7-8	E-D (Discontinuous)	8	4.22	3	0.42	0.528	0.211	0.2173	PASS		
	E-D (Continuous)	8	4.22	3	0.42	0.528	0.211	0.3801	PASS		
	D-C	8	4.22	3	0.42	0.528	0.211	0.5564	FAIL	2	0.5008
	C-B (Discontinuous)	8	4.22	3	0.42	0.528	0.211	0.2226	PASS		
	C-B (Continuous)	8	4.22	3	0.42	0.528	0.211	0.3878	PASS		
8-9	Stairs	8	4.22	3	0.42	0.528	0.211	0.8897	FAIL	4.75	0.4448
	E-D (Discontinuous)	8	4.22	3	0.42	0.528	0.211	1.037	FAIL	3.5	0.4897
	E-D (Continuous)	8	4.22	3	0.42	0.528	0.211	1.367	FAIL	4.75	0.4786
	D-C	8	4.22	3	0.42	0.528	0.211	0.3878	PASS		

Table G5: Balancing of Longitude Tendons

Appendix G.4: Max Tendons

Span Number	Slab Depth (in)	Strip Width (FT)	Strip Width (in)	Strip Area (in^2)	Initial Force (K)	Number of Tendons	Pass/Fail	Max Number of Tendons	New Number of Tendons
5-1	8	14.3	172	1373	172	7	PASS	18	-
5-2	8	14.3	172	1373	172	7	FAIL	18	17
5-3	8	14.3	172	1373	172	7	PASS	18	-
5-4	8	14.3	172	1373	172	7	PASS	18	-
5-5	8	14.3	172	1373	172	7	PASS	18	-
1-1	8	25.3	304	2429	304	12	FAIL	32	26
11-1	8	24.3	292	2333	292	11	FAIL	31	*Fails with max tendons
11-2	8	25.3	304	2429	304	12	FAIL	32	*Fails with max tendons
11-3	8	25.3	304	2429	304	12	PASS	32	-
11-4	8	20.7	248	1987	248	10	PASS	26	-
2-1	8	14	168	1344	168	7	PASS	18	-
2-2	8	14.3	172	1373	172	7	FAIL	18	17
2-3	8	14	168	1344	168	7	FAIL	18	17
2-4	8	25.3	304	2429	304	12	PASS	32	-
2-5	8	25.3	304	2429	304	12	PASS	32	-
2-6	8	14	168	1344	168	7	PASS	18	-
17-1	8	16	192	1536	192	8	PASS	20	-
16-1	8	14.1	169	1354	169	7	FAIL	18	Ignore
6-1	8	9.2	110	883	110	5	PASS	12	-
7-1	8	6.8	82	653	82	4	FAIL	9	7

Table G6: Maximum Number of Tendons per Design Strip

Appendix H: Wind and Seismic Loads – ASCE 7-10

Appendix H.1: Wind Loads

1) Risk Catagory (Table 1.5-1)

⇒ III

2) Basic Wind Speed (Fig 26.5)

V = 115 mph

3) Wind Load Parameters

3a) Directionality Factor, K_d (Table 26.6-1)

$K_d = 0.85$

3b) Exposure Catagory (26.7.3)

⇒ B

3c) Topographical Factor, K_{zt} (26.8 + Table 26.8-1)

⇒ $K_{zt} = 1.0$

3d) Gust Effect Factor, G (26.9)

i) Determine Building Natural Frequency, n_a (26.8)

- Building meets requirements

① Building Height < 300 ft ✓

② Building Height < $4L_{eff}$ ✓

$$n_a = 385 (C_w)^{0.5} / H$$

$$C_w = \frac{100}{A_B} \sum_{i=1}^{n} \left(\frac{H}{h_i}\right)^2 \frac{A_i}{\left[1 + 0.83\left(\frac{h_i}{D_i}\right)^2\right]}$$

Shear wall 1 (At CL 6.8) - NS

$A_B \approx (173' \times 51') + (42' \times 72') = 11{,}847\ ft^2$

$H = 102'$

$h_i = 102'$

$A_i = \frac{12''}{12} \times 14' = 14\ ft^2$

$D_i = 14'$

$$\left(\frac{102}{102}\right)^2 \frac{14}{\left[1 + 0.83\left(\frac{102}{14}\right)^2\right]} = 0.311$$

Shear Wall 2 (At CL B.2) - EW

$H = 102'$

$h_i = 102'$

$A_i = \frac{12''}{12} \times 21' = 21\ ft^2$

$D_i = 21'$

$$\left(\frac{102}{102}\right)^2 \frac{21}{\left[1 + 0.83\left(\frac{102}{14}\right)^2\right]} = 0.466$$

Shear Wall 3 (At west stair wall) - NS

$H = 102'$

$h_i = 68$

$A_i = \frac{12''}{12} \times 8.6' = 8.6\ ft^2$

$D_i = 8.6'$

$$\left(\frac{102}{68}\right)^2 \frac{8.6}{\left[1 + 0.83\left(\frac{68}{8.6'}\right)^2\right]} = 0.366$$

Shear Wall 4 (At South Stair wall) - EW

$H = 102'$

$h_i = 102'$

$A_i = \frac{12''}{12} \times 20.33' = 20.33\ ft^2$

$D_i = 20.33'$

$$\left(\frac{102}{102}\right)^2 \frac{20.33}{\left[1 + 0.83\left(\frac{102}{20.33}\right)^2\right]} = 0.929$$

Shear Wall 5 (At CL 5) – NS

$H = 102'$
$h_i = 102'$
$A_i = \frac{12''}{12} \times 12' = 12 ft^2$
$D_i = 12'$

$$\left(\frac{102}{102}\right)^2 \frac{12}{\left[1+0.83\left(\frac{102}{12}\right)^2\right]} = 0.197$$

Shear Wall 6 (At CL D) – EW

$H = 102'$
$h_i = 102'$
$A_i = \frac{12''}{12} \times 25.2 = 25.2 ft^2$
$D_i = 25.2'$

$$\left(\frac{102}{102}\right)^2 \frac{25.2}{\left[1+0.83\left(\frac{102}{25.2}\right)^2\right]} = 1.726$$

Shear Wall 7 (At CL 4) – NS

$H = 102'$
$h_i = 102'$
$A_i = \frac{12''}{12} \times 20' = 20 ft^2$
$D_i = 20'$

$$\left(\frac{102}{102}\right) \frac{20}{\left[1+0.83\left(\frac{102}{20}\right)^2\right]} = 0.885$$

Shear Wall 8 (At East Stair Wall) – NS

$H = 102'$
$h_i = 34'$
$A_i = \frac{12''}{12} \times 10' = 10 ft^2$
$D_i = 10'$

$$\left(\frac{102}{34'}\right)^2 \frac{10}{\left[1+0.83\left(\frac{34}{10}\right)^2\right]} = 8.495$$

Shear Wall 9 (At CL E) - EW

$H = 102'$

$h_i = 34'$

$A_i = \frac{12''}{12} \times 23.3' = 23.3 ft^2$

$D_i = 23.3'$

$$\left(\frac{102}{34}\right)^2 \frac{23.3}{\left[1 + 0.83\left(\frac{34}{23.3}\right)^2\right]} = 75.776$$

North - South

$$\sum \left(H/h_i\right)^2 \frac{A_i}{\left[1 + 0.83\left(\frac{h_i}{D_i}\right)^2\right]} = 0.311 + 0.366 + 0.197 + 0.885 + 8.495$$

$$= 10.254$$

$$C_{w,NS} = \frac{100}{11,847}(10.254) = 0.0866$$

$$n_{a,NS} = 385(0.0866)^{0.5}/102 = 1.11 \text{ Hz}$$

East - West

$$\sum \left(H/h_i\right)^2 \frac{A_i}{\left[1 + 0.83\left(h_i/D_i\right)^2\right]} = 0.466 + 0.929 + 1.726 + 75.776$$

$$= 78.897$$

$$C_{w,EW} = \frac{100}{11,847}(78.897) = 0.6660$$

$$n_{a,EW} = 385(0.6660)^{0.5}/102 = 3.08 \text{ Hz}$$

$\Rightarrow n_a > 1.0$ Hz in both directions $\Rightarrow$ Rigid Structure

iii) Rigid Buildings (6.5.8.1)

$$G = 0.925\left(\frac{(1+1.7g_Q I_{\bar{z}} Q)}{1+1.7g_v I_{\bar{z}}}\right)$$

$g_Q = 3.4$

$g_v = 3.4$

$$I_{\bar{z}} = c\left(\frac{33}{\bar{z}}\right)^{1/6} = 0.30\left(\frac{33}{0.6(102)}\right)^{1/6} = 0.271 \qquad * \ \bar{z} > z_{min} = 30'$$

N-S Direction ⇒ $Q = \sqrt{\dfrac{1}{1+0.63\left(\dfrac{B+h}{L_{\bar{z}}}\right)^{0.63}}}$

$B = 147'$

$h = 83.33'$

$$L_{\bar{z}} = \ell\left(\frac{\bar{z}}{33}\right)^{\bar{\epsilon}} = 320\left(\frac{0.6(102)}{33}\right)^{1/3} = 393.15$$

$$Q = \sqrt{\frac{1}{1+0.63\left(\frac{147+102}{393.15}\right)^{0.63}}} = \underline{\underline{0.824}} \ \text{(N-S)}$$

E-W Direction ⇒ $B = 94.33'$

$h = 102$

$L_{\bar{z}} = 393.15$

$$Q = \sqrt{\frac{1}{1+0.63\left(\frac{94.33+102}{393.15}\right)^{0.63}}} = \underline{\underline{0.843}} \ \text{(E-W)}$$

N-S Direction ⇒ $G = 0.925\left(\dfrac{(1+1.7(3.4)(0.280)(0.824))}{1+1.7(3.4)(0.280)}\right) = \underline{\underline{0.824 \ \text{(N-S)}}}$

E-W Direction ⇒ $G = 0.925\left(\dfrac{(1+1.7(3.4)(0.280)(0.843))}{1+1.7(3.4)(0.280)}\right) = \underline{\underline{0.835 \ \text{(E-W)}}}$

3e) Enclosure Classification (26.10)

⇒ enclosed

3f.) Internal Pressure Coef., GCpi (Table 26.11-1)

⇒ $GC_{pi} = \pm 0.18$

4) Velocity Pressure Exposure Coeff., Kz or Kh (Table 27.3-1)

$z_g = 1200 \quad \alpha = 7.0$

$K_z(18') = 2.01\,(18/1200)^{2/7} = 0.61$
$K_z(36) = 2.01\,(36/1200)^{2/7} = 0.74$
$K_z(52) = 2.01\,(52/1200)^{2/7} = 0.82$
$K_z(68) = 2.01\,(68/1200)^{2/7} = 0.89$
$K_z(84) = 2.01\,(84/1200)^{2/7} = 0.94$
$K_z(102) = 2.01\,(102/1200)^{2/7} = 0.99$

5) Velocity Pressure, qz (27.3.2)

$q_z = 0.00256\, K_z K_{zt} K_d V^2$

$K_{zt} = 1.0$
$K_d = 0.85$
$V^2 = 13225$

$q_z = 0.00256\, K_z (1.0)(0.85)(13225) = 28.78\, K_z$

$q_z(18) = 17.56$
$q_z(36) = 21.30$
$q_z(52) = 23.60$
$q_z(68) = 25.61$
$q_z(84) = 27.05$
$q_z(102) = 28.49$

6) External Pressure Coefficient, Cp (Fig 27.4-1 to 27.4-7)

$C_{p,w} = 0.8$

N-S Direction

$\frac{L}{B} = \frac{94.67}{147} = 0.64$

$C_{p,l} = -0.5$

E-W Direction

$\frac{L}{B} = \frac{147}{94.61} = 1.56$

$C_{p,l} = -0.388$

Roof Pressure Coeff. $\theta = \tan^{-1}(5/12) = 26.1° > 10°$

N-S Direction (windward)

$h/L = 110.5/94.67 = 1.17 \geq 1.0$

$C_{p,w} = -0.456, 0.044$

N-S Direction (Leeward)

$\theta = 26.1 > 20°$

$C_{p,l} = -0.6$

* For mansard roofs, the top horizontal surface & leeward inclined surface shall be treated as leeward surfaces from table (Fig 27.4-1 note 8.)

E-W Direction (windward)

$h/L = 110.5/147 = 0.75 \Rightarrow 0.5 < 0.75 < 1.0$

$C_{p,w} = -0.367, 0.122$

E-W Direction (Leeward)

$\theta = 26.1 > 20°$

$C_{p,l} = -0.6$

Summary of Cp Values

		Walls	Roof
N-S Direction	windward	0.8	-0.456, 0.044
	leeward	-0.5	-0.6
E-W Direction	wind ward	0.8	-0.367, 0.122
	leeward	-0.388	-0.6

7) Calculate Wind Pressures on Each Surface

Wind Pressure for Walls

⇒ See Excel Sheet for Pressures

Wind Pressure for Roofs

$P = q_h GC_p$

$q_h = q_z(110.5)$

$= 0.00256\left[2.01\left(\frac{110.5}{1200}\right)^{2/7}\right](0.85)(13225)$

$= 29.3$

N-S (windward)

$P = 29.3(0.824)(-0.456) = -11.01$ psf

$P = 29.3(0.824)(0.044) = 1.06$ psf

N-S (Leeward)

$P = 29.3(0.824)(-0.6) = -14.49$ psf

E-W Direction (windward)

$P = 29.3(0.835)(-0.367) = -8.98$ psf

$P = 29.3(0.835)(0.122) = 2.98$ psf

E-W Direction (Leeward)

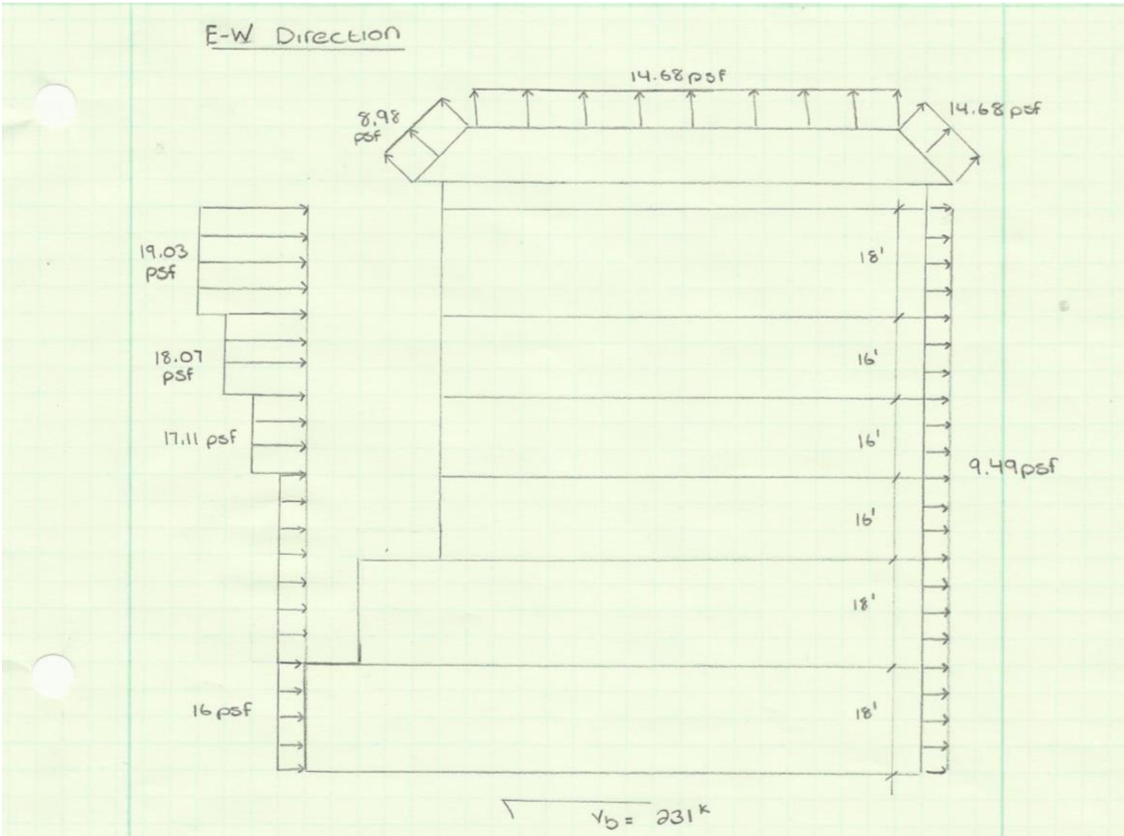
$P = 29.3(0.835)(-0.6) = -14.68$ psf

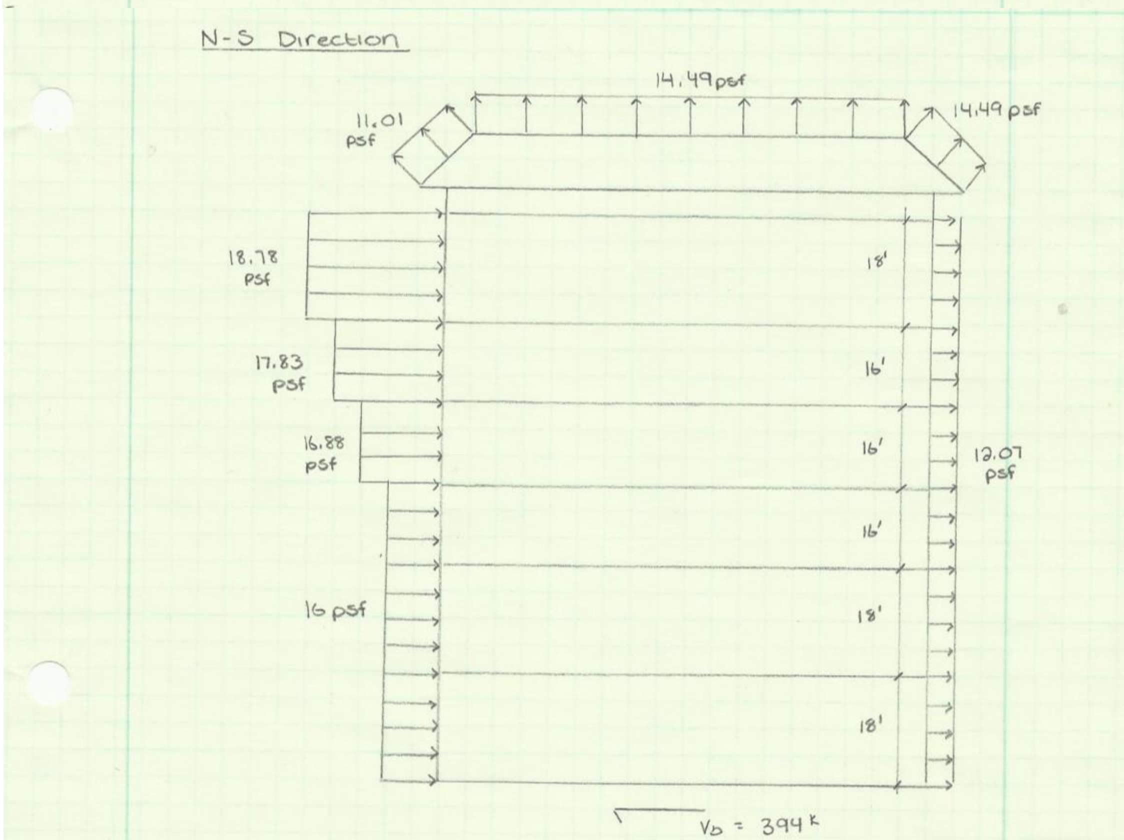
8. Calculate Wind Pressure, P

Wind Pressures (N-S Direction)					
Floor Height	q_z	Windward Pressure (PSF)	Leeward Pressure (PSF)	Trib Area (SF)	Force (K)
18	17.56	16.00	-12.07	2646	74
36	21.3	16.00	-12.07	2499	70
52	23.6	16.00	-12.07	2352	66
68	25.61	16.88	-12.07	2352	68
84	27.05	17.83	-12.07	2499	75
102	28.49	18.78	-12.07	1323	41
				Base Shear=	394

Wind Pressures (E-W Direction)					
Floor Height	q_z	Windward Pressure (PSF)	Leeward Pressure (PSF)	Trib Area (SF)	Force (K)
18	17.56	16.00	-9.49	1698	43
36	21.3	16.00	-9.49	1604	41
52	23.6	16.00	-9.49	1509	38
68	25.61	17.11	-9.49	1509	40
84	27.05	18.07	-9.49	1604	44
102	28.49	19.03	-9.49	849	24
				Base Shear=	231

NOTE: ASCE 7 - 10 Section 27.4.7 specifies that wind pressures must be greater than 16psf


E-W Direction
14.68 psf
8.98 psf
14.68 psf
19.03 psf
18.07 psf
17.11 psf
16 psf
9.49 psf
18'
16'
16'
16'
18'
18'
V_b = 231^k


N-S Direction
14.49 psf
11.01 psf
14.49 psf
18.78 psf
17.83 psf
16.88 psf
16 psf
12.07 psf
18'
16'
16'
16'
18'
18'
V_b = 394^k

Appendix H.2: Seismic Loads

1) Exemptions (11.1.2)

- Building not exemp

2) Design Specural Responce Acceleration (11.4)

a) Site Class (11.4.2)

- B

b) Acceleration Parameters (11.4.3 + Chp 22)

$S_s = 0.332g$
$S_1 = 0.094g$

c) Check to see if adjust for site class (11.4.2 + 11.4.3)

$S_{DS} = \frac{2}{3} S_{MS} = \frac{2}{3}(0.332) = 0.221$

$S_{D1} = \frac{2}{3} S_{M1} = \frac{2}{3}(0.094) = 0.063$

* Cant use simplified method b/c building doesnt meet requirements (12.14)

3) Seismic Design Catagory (11.6)

Occupancy Catagory III ⇒ B
$0.167 < S_{DS} < 0.33$

4) Analysis Procedure Selection (12.6)

⇒ Equivalent lateral force Analysis

5) Determine R (Table 12.2-1)

⇒ Ordinary Reinforced Shear Walls ⇒ $R = 4$

6) Importance Factor (Table 1.5-2)

⇒ Risk Catagory III ⇒ $I_e = 1.25$

7) Find Period T (12.8.2.1)

$T_a = C_t h_n^x$

$h_n = 119'$
$C_t = 0.02$
$x = 0.75$

$T_a = (0.02)(119)^{0.75} = 0.721$

8) Determine T_L (Fig 22-12 to 22-16)

⇒ T_L = 12 sec

9) Determine Seismic Responce Coefficients, C_s (12.8.1.1)

$$C_s \leq \frac{S_{DS}}{R/I} = \frac{0.221}{(4/1.25)} = 0.0691$$

Check $T_a = 0.721 < T_L = 12$

$$C_s \leq \frac{S_{D1}}{T(R/I)} = \frac{0.063}{.721(4/1.25)} = 0.0273$$

C_s = min | 0.0691, 0.0273 ⇒ 0.0273

* C_s shall not be less than

max | $0.044(0.221)(1.25) = 0.012$, 0.01 ⇒ 0.012

⇒ $C_s = 0.0273 > 0.012$ ✓

10) Calculate the seismic weight

Roof

Dead Load = (125 + 11 + 10)(9905SF)/1000 = 1447^k

Distributed Line Load = (133.1)(357)/1000 = 47.5^k

Mechanical Equipment = (15 + 50) = 65^k

Total Load = 1559.5^k

Floor

Dead Loads: Slab = 125psf

Misc. Dead = 10PSF

24"x30" Beams = 500plf
24"x24" Beams = 350plf
16x24 Beams = 233plf

⇒ See excel sheet for weight calculations

Calculation of Loads:

Calculation of Floor Weights

Level	Slab + Partitions +Misc DL (PSF)	Floor Area (SF)	24"x30" Beams (PLF)	24"x30" Beams (LF)	24"x24" Beams (PSL)	24"x24" Beams (LF)	16"x24" Beams (PLF)	16"x24" Beams (LF)	Weight (K)
Roof	146	9905	500	122	350	223	233	78	1716
6	162	10258	500	122	350	178	233	78	1803
5	162	10379	500	122	350	178	233	78	1823
4	162	11115	500	145.3	350	202	233	78	1962
3	162	12513	500	145.3	350	152	233	78	2171
2	162	12859	500	145.3	350	98	233	63	2205

Calculation of Effective Seismic Weight

Level	Area of General Collections (SF)	Live Load (PSF)	Total Load (K)	25% of Live Load (K)
Roof	0	150	0	0
6	3146	150	472	118
5	3034	150	455	114
4	372	150	56	14
3	4364	150	655	164
2	796	150	119	30

* ACSE 12.7.2 - General collections are considered as live load storage

Calculation of Column Weights

Level	Column Height Below (FT)	Column Height Above (FT)	Column Wieght Below (PLF)	Column Wieght Above (PLF)	Column Wieght (K)
Roof	9	0	10800	0	97
6	8	9	10800	10800	184
5	8	8	10200	10800	168
4	8	8	12000	10200	178
3	9	8	7800	12000	166
2	9	9	3600	7800	103

Wall Weights

Typical exterior wall:	91.875	PSF
16" foundation wall:	200	PSF
24" foundation wall:	300	PSF
30" foundation wall:	375	PSF
33" foundation wall:	412.5	PSF

Calculation of Exterior Wall Weights

Level	Wall Height Below (FT)	Wall Height Above (FT)	Length of Exterior Wall Below (FT)	Length of Exterior Wall Above (FT)	Length of 16" Foundation Wall Below (FT)	Length of 16" Foundation Wall Above (FT)	Length of 24" Foundation Wall Below (FT)	Length of 24" Foundation Wall Above (FT)	Length of 30" Foundation Wall Below (FT)	Length of 30" Foundation Wall Above (FT)	Length of 33" Foundation Wall Below (FT)	Length of 33" Foundation Wall Above (FT)	Weight of Exterior Wall (K)	Weight of Foundation Walls (K)	Total Wall Weight (K)
Roof	9	0	492	0	0	0	0	0	0	0	0	0	407	0	407
6	8	9	492	492	0	0	0	0	0	0	0	0	768	0	768
5	8	8	453	492	0	0	77	0	0	0	0	0	695	186	881
4	8	8	377	453	0	0	121	77	0	0	35	0	611	591	1202
3	9	8	270	377	13	0	172	121	31	0	79	35	500	1290	1791
2	9	9	54	270	258	13	173	172	90	31	79	79	267	2411	2679

Weight of Shear W	150	PSF

Calculation of Shear Wall Weights

Level	Wall Height Below (FT)	Wall Height Above (FT)	Length of Shear Wall 1 Below (FT)	Length of Shear Wall 1 Above (FT)	Length of Shear Wall 2 Below (FT)	Length of Shear Wall 2 Above (FT)	Length of Shear Wall 3 Below (FT)	Length of Shear Wall 3 Above (FT)	Length of Shear Wall 4 Below (FT)	Length of Shear Wall 4 Above (FT)	Length of Shear Wall 5 Below (FT)	Length of Shear Wall 5 Above (FT)	Length of Shear Wall 6 Below (FT)	Length of Shear Wall 6 Above (FT)	Length of Shear Wall 7 Below (FT)	Length of Shear Wall 7 Above (FT)	Length of Shear Wall 8 Below (FT)	Length of Shear Wall 8 Above (FT)	Length of Shear Wall 9 Below (FT)	Length of Shear Wall 9 Above (FT)	Total Wall Weight (K)
Roof	9	0	14	0	21	0	0	0	15.2	0	12	0	25.6	0	20	0	10	0	23.3	0	190
6	8	9	14	14	21	21	0	0	19.3	15.2	12	12	25.6	25.6	20	20	10	10	23.3	23.3	365
5	8	8	14	14	21	21	8.6	0	20.3	19.3	12	12	25.6	25.6	20	20	0	10	0	23.3	320
4	8	8	14	14	21	21	8.6	8.6	20.3	20.3	12	12	25.6	25.6	20	20	0	0	0	0	292
3	9	8	14	14	21	21	8.6	8.6	20.3	20.3	12	12	25.6	25.6	20	20	0	0	0	0	310
2	9	9	14	14	30	21	8.6	8.6	20.3	20.3	12	12	25.6	25.6	20	20	0	0	0	0	340

11) Base Shear, V (12.8.1)

$$V = C_s W$$

$$= (0.0273)(22558)$$

$$= 615.8^k$$

12) Vertical Distribution of Forces (12.8.3)

$$F_x = C_{vx} V = \left[\frac{w_x h_x^k}{\sum w_x h_x^k}\right] V$$

k: Ta = 0.721 ⇒ 0.5 < 0.721 < 2.5

$$\frac{2.5 - 0.5}{2 - 1} = \frac{2 - 0.721}{2 - k} \Rightarrow k = 1.11$$

⇒ See excel table on next page

12. Vertical Distribution of Forces

E-W Direction

k=	1.11	Cs=	0.0273
Vb=	615.8 Kips		

Calculation of Story Forces

Level	Floor-to-Floor Height (FT)	Floor Dead Loads (K)	Wall Loads (K)	Shear Wall Weights (K)	Column Loads (K)	Total Wieght = w_i (K)	h_i (FT)	$w_i h_i^k$ (K-FT)	C_{vx}	F (K)
Roof	9	1716	407	190	97	2410	102	963012	0.210	129
6	17	1921	768	365	184	3238	84	1077339	0.234	144
5	16	1937	881	320	168	3305	68	871800	0.190	117
4	16	1976	1202	292	178	3647	52	722020	0.157	97
3	17	2335	1791	310	166	4602	36	621328	0.135	83
2	18	2234	2679	340	103	5356	18	340687	0.074	46
					Sum=	22558	Sum=	4596186	1.000	616

N-S Direction

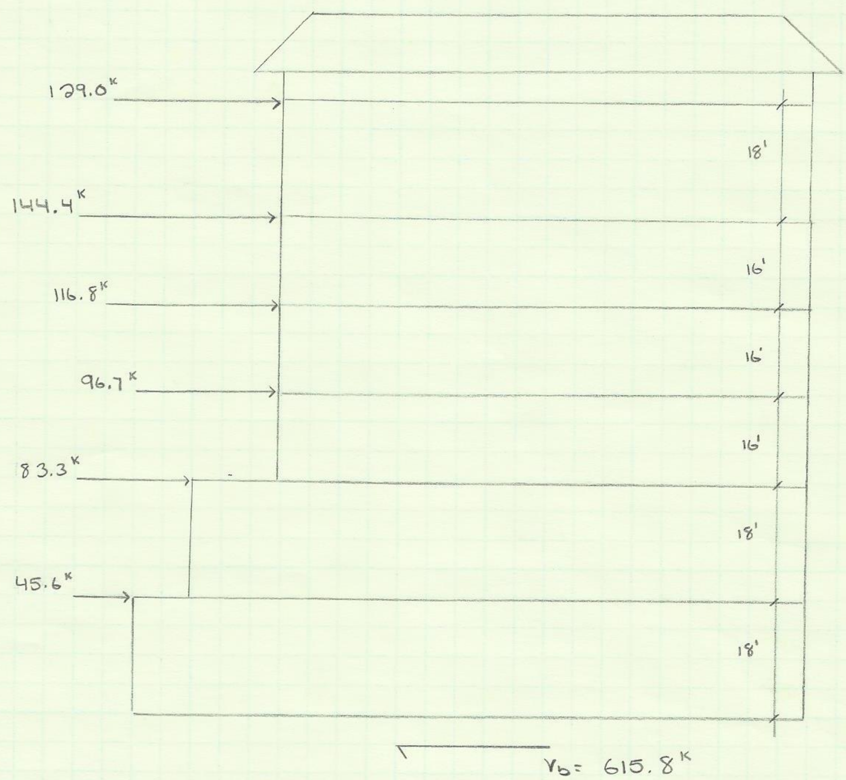
k=	1.11	Cs=	0.0147
Vb=	331.3 Kips		

Calculation of Story Forces

Level	Floor-to-Floor Height (FT)	Floor Dead Loads (K)	Wall Loads (K)	Shear Wall Weights (K)	Column Loads (K)	Total Wieght = w_i (K)	h_i (FT)	$w_i h_i^k$ (K-FT)	C_{vx}	F (K)
Roof	9	1716	407	190	97	2410	102	963012	0.210	69
6	17	1921	768	365	184	3238	84	1077339	0.234	78
5	16	1937	881	320	168	3305	68	871800	0.190	63
4	16	1976	1202	292	178	3647	52	722020	0.157	52
3	17	2335	1791	310	166	4602	36	621328	0.135	45
2	18	2234	2679	340	103	5356	18	340687	0.074	25
					Sum=	22558	Sum=	4596186	1.000	331

Note: Building periods originally calculated using approximate Ta equation. Once lateral model was complete building periods for both directions were able to be determined and a Cs value for each direction was calculated.

Story Forces



Appendix I: Lateral System Analysis

Location of Shear Walls

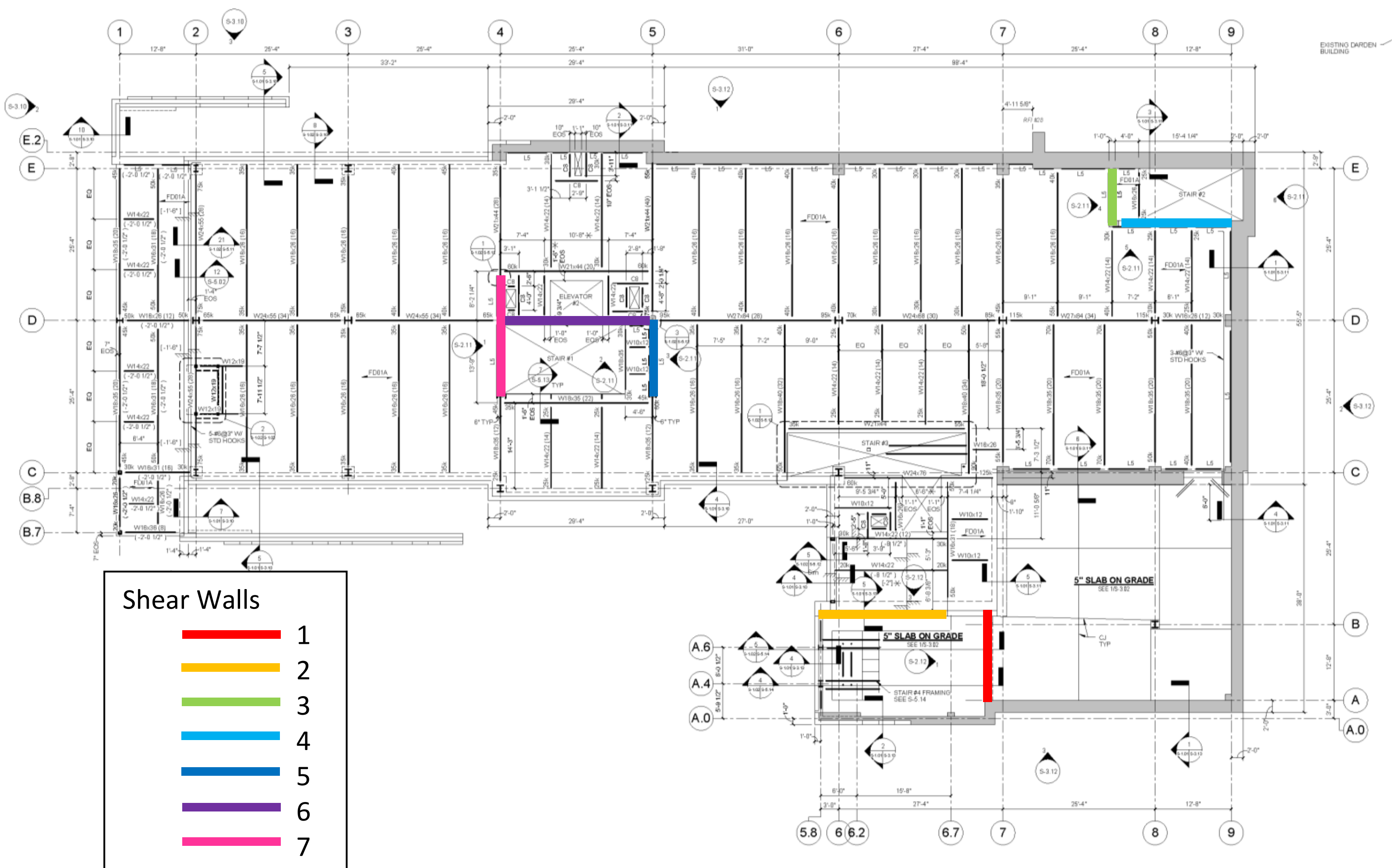


Figure I1: Location of Shear Walls

Modeling Decisions

Due to the large soil loads on the structure, the design involves a significant number of foundation walls. For this analysis, only the shear walls were modeled. This modification was made in order to be able to analyze the shear walls under the full lateral forces without the foundation walls providing increase lateral resistance. The foundation walls are designed to act as either a pined or fixed connection at the base with supports at each floor level. Due to this design, the soil forces were still used in the analysis of the building's lateral system, even though no foundation walls were modeled.

The shear walls were modeled as membranes. Membranes have no out-of-plane stiffness and therefore will take no out-of-plane shear forces.

Shear wall 1, 2, 5, 6, and 7 were modeled with pin supports at the base. In the structure these shear walls are supported either by strip footings with spread footings at each end, or just by strip footings. These base conditions do not justify the use of a fixed connection in the model.

Shear walls 3 and 4 were modeled with fixed supports at the base. In the structure these shear walls rest on a mat foundation that is located in the North-East corner of building. This base condition justifies the use of a fixed condition in the model.

The diaphragm was modeled as rigid. This allowed the transfer of lateral forces to the shear walls without providing extra resistance. The floor system in the New Library is a composite floor system which allows the lateral forces to be transferred to the shear walls.

The openings in the diaphragm and shear walls were not modeled. This was due to the complexity of modeling the struts and collectors required to channel the diaphragm loads into the shear walls along the full wall length. This decision had minimal negative impact on the model.

All of the wall sections were modeled to consider the effects of cracked sections on the deflection of the lateral system. Per ACI318-11 8.8.2, the member stiffness should be modified through section properties which decreased the wall section stiffness by 65%.

For the 2D verification of the model a slight separation between core walls was added in order to ensure that the program would not treat the shear walls as a C or modified WF section. ETABS uses finite element analysis to distribute the forces. By doing this the program considers an effective length for the shear walls. The walls could be verified by hand when there are connected, but effective wall lengths would need to be approximated. For member spot checks and drift checks the walls were reconnected.

Verification of Model

Before using the lateral model to distribute the shear forces to the shear walls, the model was checked to determine if it was reporting accurate data. This was done by applying a 1000 kip load in the x-direction to the center of mass at the roof level. The first verification was of the story forces and story moments, shown in **Figure I2**. This was done to make sure that each story was receiving 1000 kips and each story was receiving a moment equal to 1000 multiplied by the story's distance from the roof level.

Story Forces

1 of 6 Reload Apply

Story	Load Case/Combo	Location	P kip	VX kip	VY kip	T kip-ft	MX kip-ft	MY kip-ft
Roof	TEST - X	Bottom	0	-1000	0	54330	0	-18000
Level 6	TEST - X	Bottom	0	-1000	0	54330	0	-34000
Level 5	TEST - X	Bottom	0	-1000	0	54330	0	-50000
Level 4	TEST - X	Bottom	0	-1000	0	54330	0	-66000
Level 3	TEST - X	Bottom	0	-1000	0	54330	0	-84000
Level 2	TEST - X	Bottom	0	-1000	0	54330	0	-102000

Figure I2: Story Forces and Moments

The next verification was that of the in-plane shear force contours, shown in **Figures I3** and**FigureI4.** It was verified that the three shear walls acting in the x-direction had the largest contour lines due to the direct shear forces, while the remaining four shear walls had minimal contour lines due to torsional shear forces.

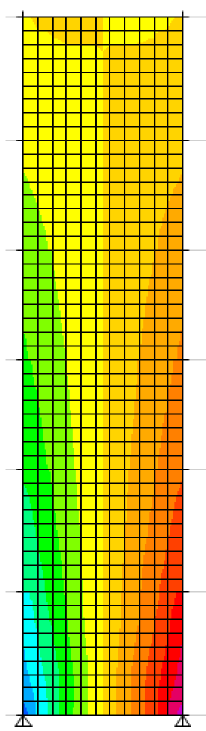


Figure I3: Shear Force Contours –In-Plane Shear Wall

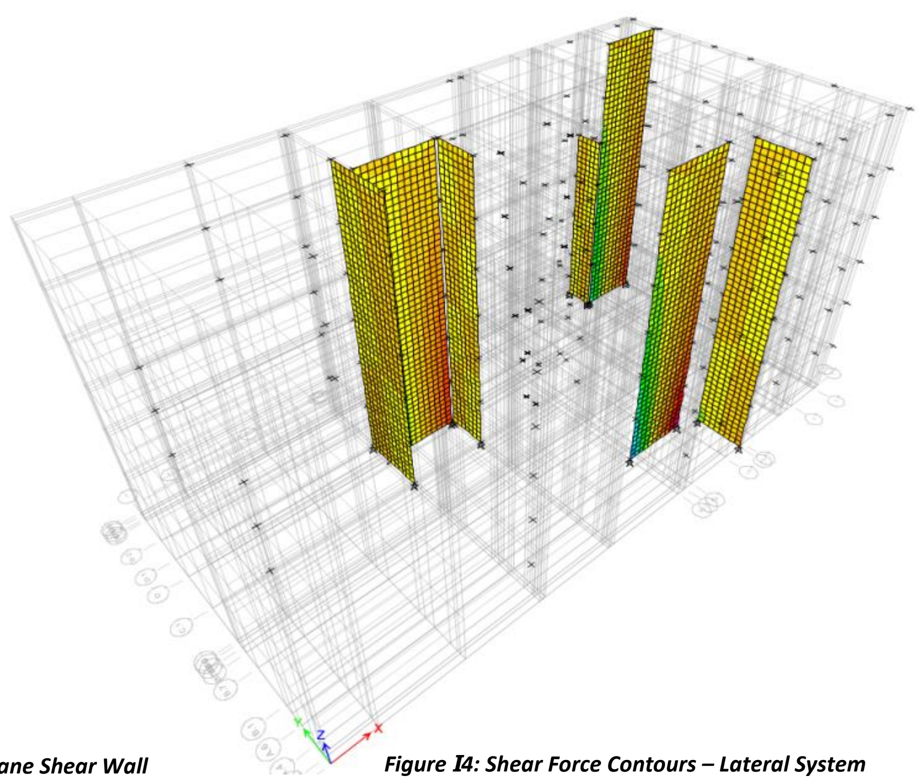


Figure I4: Shear Force Contours – Lateral System

The last verification was a brief check of the distribution of forces to each lateral element at level 2.

Distribution

In order to check the distribution of forces, the relative stiffness of each element was calculated.**TableI1**below shows the relative stiffness of each shear wall, and **Table I2** shows the forces from ETABS. **Figure I5** below shows the direction of direct shear forces and torsional shear forces in shear walls 2, 4, and 6. Based on the relative stiffness of each shear wall, it is expected that SW2 would have the highest shear forces followed by SW 6 and 4 respectively. The shear forces from the model match this expectation. It is also important to notice that the torsional shears will cause the shear in SW2 to decrease while increasing the shear in SW4 and SW6. The shear forces from the model also match these expectations.

Relative Stiffness of Shear Walls						
Shear Wall	E (ksi)	h (in)	b (in)	t (in)	k (K/in)	Relative K X–Direction
2	3605	216	260.0	33	38805	1
4	3605	216	238.3	12	12485	0.322
6	3605	216	280.0	12	15599	0.402

Table I1: Relative Stiffness of Shear Walls

Shear Forces from ETABS	
Shear Wall	Shear Force (k)
2	450.148
4	249.338
6	300.514

Table I2:ETABS Shear Forces

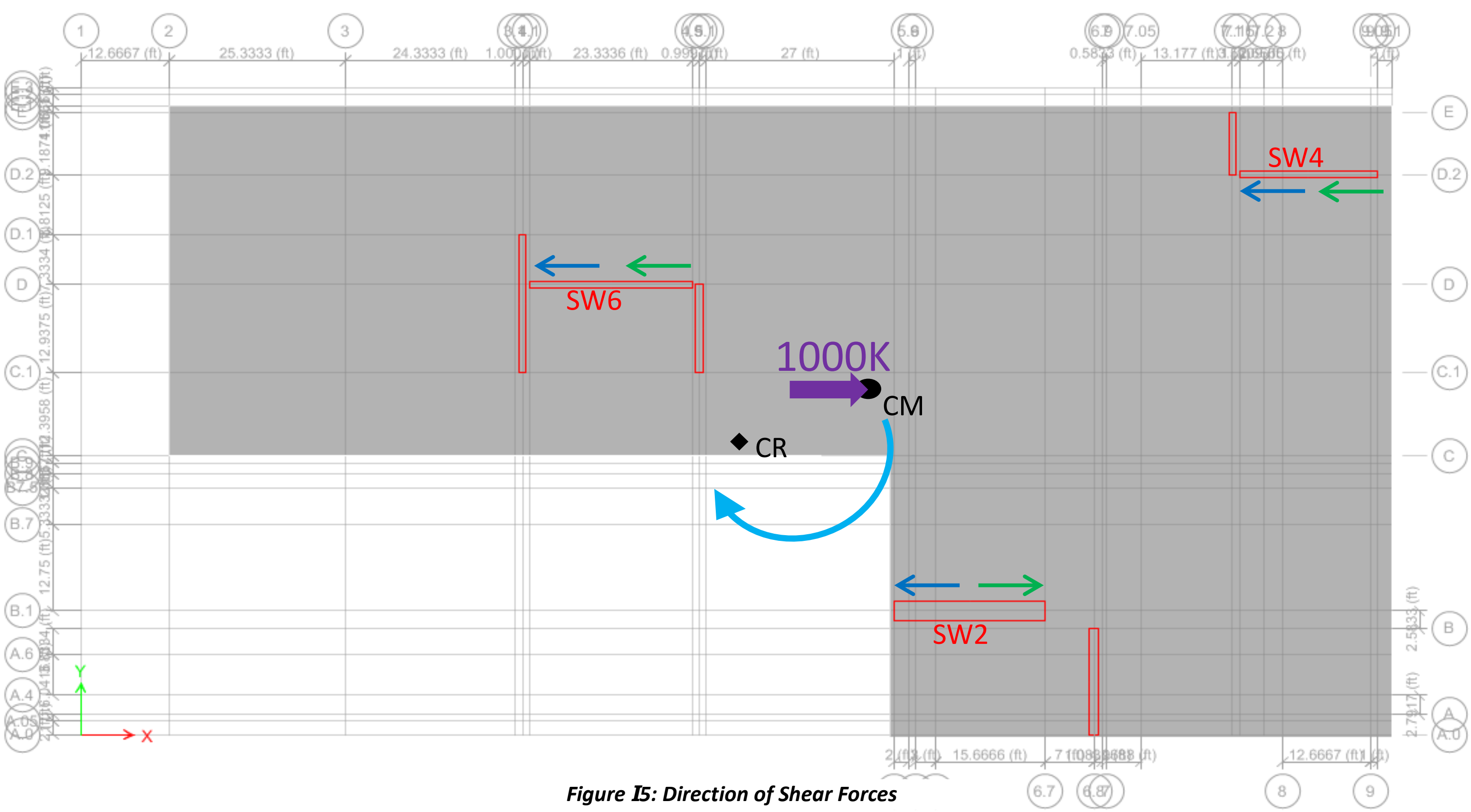


Figure I5: Direction of Shear Forces

Summation of Forces

The equilibrium of the model was then verified in both the x and y directions. Figure I6 below shows the shear forces in each shear wall in the model.

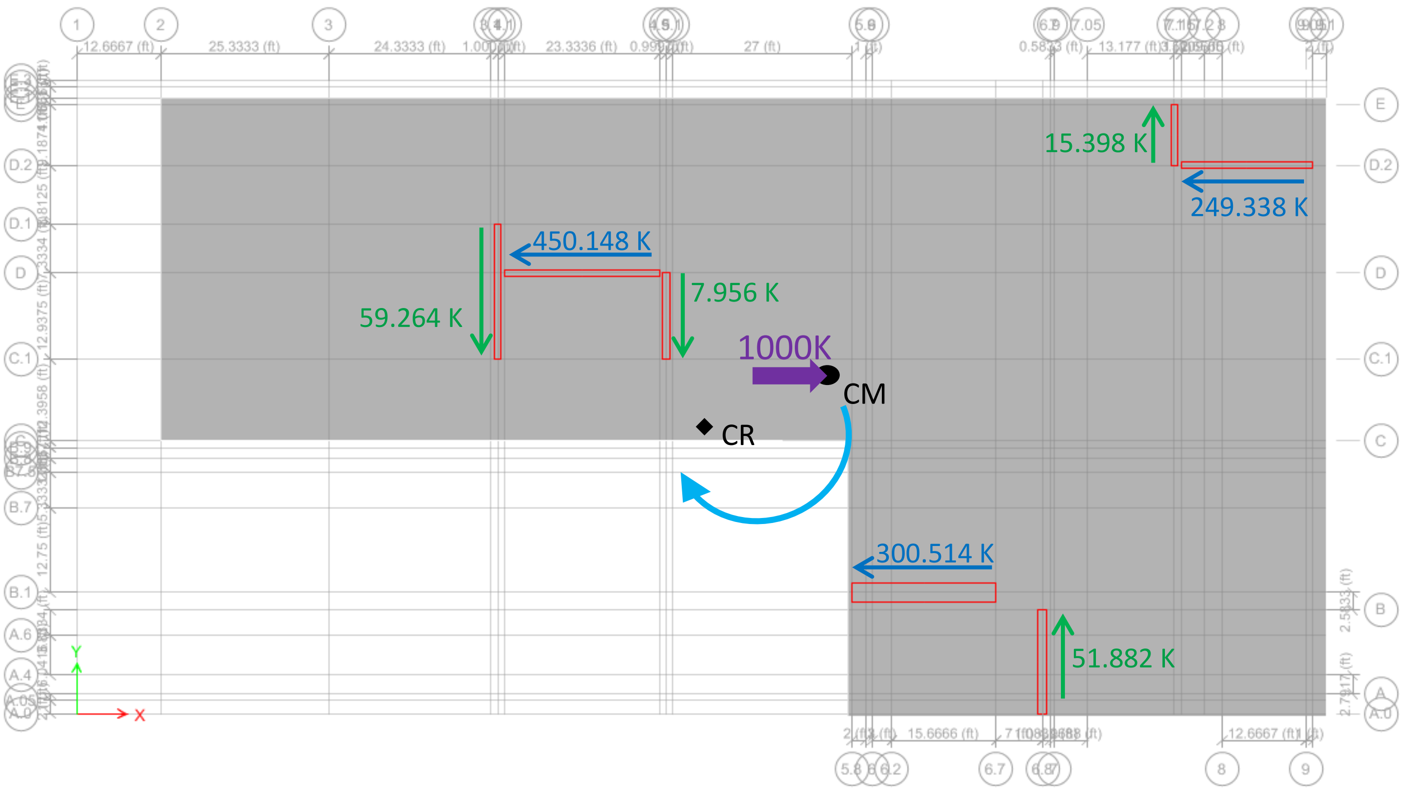


Figure I6: Shear Forces

$\sum F_x = 1000 - 450.148 - 249.338 - 300.514 = 0$

$\sum F_y = -59.264 - 7.956 + 15.398 + 51.882 = 0$

Torsional Forces (With Respect to CR)

It was also important to notice that the torsional shears were in the correct direction with respect to the center of rigidity. The offset between the center of mass and center of rigidity will cause a clockwise rotation. All shears to the left of the CR are in the –Y direction and all shears to the right of the CR are in the +Y direction.

Building Properties

Below **Table I3** shows the location of the center of mass for each level of the New Library. The center of mass for each level was calculated by hand. ETABS is able to calculate the center of mass for the structure, but this requires the mass of the structure to be included in the program. Due to the fact that this was strictly a lateral model, and no gravity elements were included, no masses were to be added to the model. The center of mass was used in the application of seismic forces.

Center of Mass		
Level	X-Direction	Y-Direction
Roof	121.72	54.00
6	125.67	54.62
5	122.09	56.01
4	120.31	59.34
3	110.01	59.04
2	113.20	54.33

TableI3: Center of Mass

Below **Table I4** shows the location of the center of rigidity for each level of the New Library. ETABS calculates the center of rigidity of each level in the model.

Center of Rigidity		
Level	X-Direction	Y-Direction
Roof	94.3337	50.0655
6	94.8591	49.1726
5	95.367	48.0842
4	96.0189	46.5582
3	97.0962	44.51
2	100.0302	41.9675

TableI4: Center of Rigidity

Below **Table I5** shows the location of the center of rigidity for each level of the New Library. ETABS calculates this location automatically when a wind load is applied, and the locations were verified.

Center of Pressure		
Level	X-Direction	Y-Direction
Roof	113	46.344
6	113	46.344
5	113	46.344
4	100.333	46.344
3	100.333	46.344
2	100.333	46.344

Table I5: Center of Pressure

Appendix J: Drainage Breadth

Appendix J.1: Bituthane System 4000 Tech Sheets

Grace Below Grade Waterproofing

BITUTHENE® SYSTEM 4000

Self-adhesive HDPE waterproofing membrane with super tacky compound for use with patented, water-based System 4000 Surface Conditioner

Description

Bituthene® System 4000 is a 1.5 mm (1⁄16 in.) flexible, pre-formed waterproof membrane which combines a high performance, cross laminated, HDPE carrier film with a unique, super tacky, self-adhesive rubberized asphalt compound.

System 4000 Surface Conditioner is a unique, water-based, latex surface treatment which imparts an aggressive, high tack finish to the treated substrate. It is specifically formulated to bind site dust and concrete efflorescence, thereby providing a suitable surface for the Bituthene System 4000 Waterproofing Membrane.

Conveniently packaged in each roll of membrane, System 4000 Surface Conditioner promotes good initial adhesion and, more importantly, excellent permanent adhesion of the Bituthene System 4000 Waterproofing Membrane. The VOC (Volatile Organic Compound) content of this product is 100 g/L.

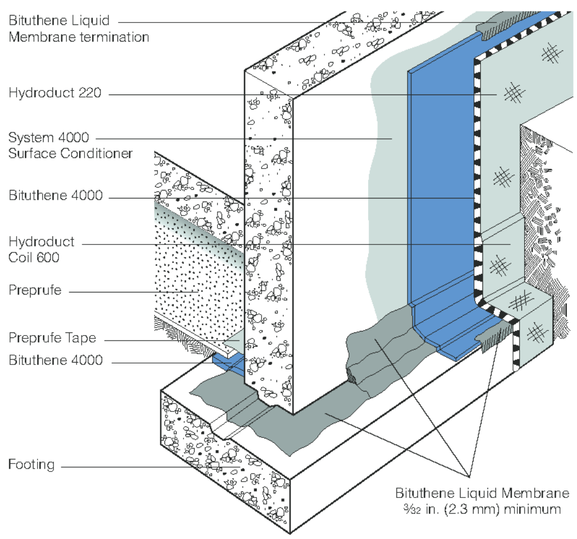
Architectural and Industrial Maintenance Regulations limit the VOC content in products classified as Architectural Coatings. Refer to Technical Letters at graceconstruction.com for most current list of allowable limits.

Advantages

- **Excellent adhesion**—special adhesive compound engineered to work with high tack System 4000 Surface Conditioner
- **Cold applied**—simple application to substrates, especially at low temperatures
- **Reduced inventory and handling costs**—System 4000 Surface Conditioner is included with each roll of membrane
- **Wide application temperature range**—excellent bond to self and substrate from 25°F (-4°C) and above

Product Advantages

- Excellent adhesion
- Cold applied
- Reduced inventory and handling costs
- Wide application temperature range
- Overlap security
- Cross laminated, high density polyethylene carrier film
- Flexible
- Ripcord



Drawings are for illustration purposes only.
Please refer to graceconstruction.com for specific application details.

- **Overlap security**—minimizes margin for error under site conditions
- **Cross laminated, high density polyethylene carrier film**—provides high tear strength, puncture and impact resistance
- **Flexible**—accommodates minor structural movements and will bridge shrinkage cracks
- **Ripcord®**—this split release on demand feature allows the splitting of the release paper into two (2) pieces for ease of installation in detailed areas

Use

Bituthene is ideal for waterproofing concrete, masonry and wood surfaces where in-service temperatures will not exceed 135°F (57°C). It can be applied to foundation walls, tunnels, earth sheltered structures and split slab construction, both above and below grade. (For above grade applications, see *Above Grade Waterproofing Bituthene System 4000*.)

Bituthene is 1⁄16 in. (1.5 mm) thick, 3 ft (0.9 m) wide and 66.7 ft (20 m) long and is supplied in rolls. It is unrolled sticky side down onto concrete slabs or applied onto vertical concrete faces primed with System 4000 Surface Conditioner. Continuity is achieved by overlapping a minimum 2 in. (50 mm) and firmly rolling the joint.

Bituthene is extremely flexible. It is capable of bridging shrinkage cracks in the concrete and will accommodate minor differential movement throughout the service life of the structure.

Application Procedures

Safety, Storage and Handling Information

Bituthene products must be handled properly. Vapors from solvent-based primers and mastic are harmful and flammable.
For these products, the best available information on safe handling, storage, personal protection, health and environmental considerations has been gathered. Material Safety Data Sheets (MSDS) are available at graceconstruction.com and users should acquaint themselves with this information. Carefully read detailed precaution statements on product labels and the MSDS before use.

Surface Preparation

Surfaces should be structurally sound and free of voids, spalled areas, loose aggregate and sharp protrusions. Remove contaminants such as grease, oil and wax from exposed surfaces. Remove dust, dirt, loose stone and debris. Concrete must be properly dried (minimum 7 days for normal structural concrete and 14 days for lightweight structural concrete).

If time is critical, Bituthene Primer B2 or Bituthene Primer B2 LVC may be used to allow priming and installation of membrane on damp surfaces or green concrete. Priming may begin in this case as soon as the concrete will maintain structural integrity. Use form release agents which will not transfer to the concrete. Remove forms as soon as possible from below horizontal slabs to prevent entrapment of excess moisture. Excess moisture may lead to blistering of the membrane. Cure concrete with clear, resin-based curing compounds which do not contain oil, wax or pigment. Except with Bituthene Primer B2 or Bituthene Primer B2 LVC, allow concrete to thoroughly dry following rain. Do not apply any products to frozen concrete.

Repair defects such as spalled or poorly consolidated areas. Remove sharp protrusions and form match lines. On masonry surfaces, apply a parge coat to rough concrete block and brick walls or trowel cut mortar joints flush to the face of the concrete blocks.

Temperature

- Apply Bituthene System 4000 Membrane and Conditioner only in dry weather and when air and surface temperatures are 25°F (-4°C) or above.
- Apply Bituthene Primer B2 or Bituthene Primer B2 LVC in dry weather above 25°F (-4°C). (See separate product information sheet.)

Conditioning

Bituthene System 4000 Surface Conditioner is ready to use and can be applied by spray or roller. For best results, use a pump-type air sprayer with fan tip nozzle, like the Bituthene System 4000 Surface Conditioner Sprayer, to apply the surface conditioner.

Apply Bituthene System 4000 Surface Conditioner to clean, dry, frost-free surfaces at a coverage rate of 300 ft²/gal (7.4 m²/L). Coverage should be uniform. Surface conditioner should not be applied so heavily that it puddles or runs. **Do not apply conditioner to Bituthene membrane.**

Allow Bituthene System 4000 Surface Conditioner to dry one hour or until substrate returns to its original color. At low temperatures or in high humidity conditions, dry time may be longer.

Bituthene System 4000 Surface Conditioner is clear when dry and may be slightly tacky. In general, conditioning should be limited to what can be covered within 24 hours. In situations where long dry times may prevail, substrates may be conditioned in advance. Substrates should be reconditioned if significant dirt or dust accumulates.

Before surface conditioner dries, tools should be cleaned with water. After surface conditioner dries, tools should be cleaned with mineral spirits. Mineral spirits is a combustible liquid which should be used only in accordance with manufacturer's recommendations. **Do not use solvents to clean hands or skin.**

Corner Details

The treatment of corners varies depending on the location of the corner. For detailed information on Bituthene Liquid Membrane, see separate product information sheet.

- At wall to footing inside corners

  Option 1: Apply membrane to within 1 in. (25 mm) of base of wall. Treat the inside corner by installing a ¾ in. (20 mm) fillet of Bituthene Liquid Membrane. Extend Bituthene Liquid Membrane at least 2½ in. (65 mm) onto footing, and 2½ in. (65 mm) onto wall membrane.

  Option 2: Treat the inside corner by installing a ¾ in. (20 mm) fillet of Bituthene Liquid Membrane. Apply 12 in. (300 mm) wide strip of sheet membrane centered over fillet. Apply wall membrane over inside corner and extend 6 in. (150 mm) onto footing. Apply 1 in. (25 mm) wide troweling of Bituthene Liquid Membrane over all terminations and seams within 12 in. (300 mm) of corner.

- At footings where the elevation of the floor slab is 6 in. (150 mm) or more above the footing, treat the inside corner either by the above two methods or terminate the membrane at the base of the wall. Seal the termination with Bituthene Liquid Membrane.

Joints

Properly seal all joints with waterstop, joint filler and sealant as required. Bituthene membranes are not intended to function as the primary joint seal. Allow sealants to fully cure. Pre-strip all slab and wall cracks over 1⁄16 in. (1.5 mm) wide and all construction and control joints with 9 in. (230 mm) wide sheet membrane strip.

Application on Horizontal Surfaces

(Note: Preprufe® pre-applied membranes are strongly recommended for below slab or for any application where the membrane is applied before concreting. See Preprufe product information sheets.)

Apply membrane from the low point to the high point so that laps shed water. Overlap all seams at least 2 in. (50 mm). Stagger all end laps. Roll the entire membrane firmly and completely as soon as possible. Use a linoleum roller or standard water-filled garden roller less than 30 in. (760 mm) wide, weighing a minimum of 75 lbs (34 kg) when filled. Cover the face of the roller with a resilient material such as a ½ in. (13 mm) plastic foam or two wraps of indoor-outdoor carpet to allow the membrane to fully contact the primed substrate. Seal all T-joints and membrane terminations with Bituthene Liquid Membrane at the end of the day.

Protrusions and Drains

Apply membrane to within 1 in. (25 mm) of the base of the protrusion. Apply Bituthene Liquid Membrane 0.1 in. (2.5 mm) thick around protrusion. Bituthene Liquid Membrane should extend over the membrane a minimum of 2½ in. (65 mm) and up the penetration to just below the finished height of the wearing course.

Vertical Surfaces

Apply membrane in lengths up to 8 ft (2.5 m). Overlap all seams at least 2 in. (50 mm). On higher walls apply membrane in two or more sections with the upper overlapping the lower by at least 2 in. (50 mm). Roll all membrane with a hand roller.

Terminate the membrane at grade level. Press the membrane firmly to the wall with the butt end of a hardwood tool such as a hammer handle or secure into a reglet. Failure to use heavy pressure at terminations can result in a poor seal. A termination bar may be used to ensure a tight seal. Terminate the membrane at the base of the wall if the bottom of the interior floor slab is at least 6 in. (150 mm) above the footing. Otherwise, use appropriate inside corner detail where the wall and footing meet.

Membrane Repairs

Patch tears and inadequately lapped seams with membrane. Clean membrane with a damp cloth and dry. Slit fishmouths and repair with a patch extending 6 in. (150 mm) in all directions from the slit and seal edges of the patch with Bituthene Liquid Membrane. Inspect the membrane thoroughly before covering and make any repairs.

Drainage

Hydroduct® drainage composites are recommended for both active drainage and protection of the membrane. See Hydroduct product information sheets.

Protection of Membrane

Protect Bituthene membranes to avoid damage from other trades, construction materials or backfill. Place protection immediately in temperatures above 77°F (25°C) to avoid potential for blisters.

- On vertical applications, use Hydroduct 220 Drainage Composite. Adhere Hydroduct 220 Drainage Composite to membrane with Preprufe Detail Tape. Alternative methods of protection are to use 1 in. (25 mm) expanded polystyrene or ¼ in. (6 mm) extruded polystyrene that has a minimum compressive strength of 8 lbs/in.^{2} (55 kN/m^2). Such alternatives do not provide

System 4000 Surface Conditioner Sprayer

The Bituthene System 4000 Surface Conditioner Sprayer is a professional grade, polyethylene, pump-type, compressed air sprayer with a brass fan tip nozzle. It has a 2 gal (7.6 L) capacity. The nozzle orifice and spray pattern have been specifically engineered for the optimum application of Bituthene System 4000 Surface Conditioner.

Hold nozzle 18 in. (450 mm) from substrate and squeeze handle to spray. Spray in a sweeping motion until substrate is uniformly covered.

Sprayer should be repressurized by pumping as needed. For best results, sprayer should be maintained at high pressure during spraying.

To release pressure, invert the sprayer and spray until all compressed air is released.

Maintenance

The Bituthene System 4000 Surface Conditioner Sprayer should perform without trouble for an extended period if maintained properly.

Sprayer should not be used to store Bituthene System 4000 Surface Conditioner. The sprayer should be flushed with clean water immediately after spraying. For breaks in the spray operation of one hour or less, invert the sprayer and squeeze the spray handle until only air comes from the nozzle. This will avoid clogging.

Should the sprayer need repairs or parts, call the maintenance telephone number on the sprayer tank (800-323-0620).

positive drainage to the system. If ¼ in. (6 mm) extruded polystyrene protection board is used, backfill should not contain sharp rock or aggregate over 2 in. (50 mm) in diameter. Adhere polystyrene protection board with Preprufe Detail Tape.

- In mud slab waterproofing, or other applications where positive drainage is not desired and where reinforced concrete slabs are placed over the membrane, the use of ¼ in. (6 mm) hardboard or 2 layers of ⅛ in. (3 mm) hardboard is recommended.

Insulation

Always apply Bituthene membrane directly to primed or conditioned structural substrates. Insulation, if used, must be applied over the membrane. Do not apply Bituthene membranes over lightweight insulating concrete.

Backfill

Place backfill as soon as possible. Use care during backfill operation to avoid damage to the waterproofing system. Follow generally accepted practices for backfilling and compaction. Backfill should be added and compacted in 6 in. (150 mm) to 12 in. (300 mm) lifts.

For areas which cannot be fully compacted, a termination bar is recommended across the top termination of the membrane.

Placing Steel

When placing steel over properly protected membrane, use concrete bar supports (dobies) or chairs with plastic tips or rolled feet to prevent damage from sharp edges. Use special care when using wire mesh, especially if the mesh is curled.

Approvals

- City of Los Angeles Research Report RR 24386
- Miami-Dade County Code Report NOA 04-0114.03
- U.S. Department of Housing and Urban Development (HUD) HUD Materials Release 628E
- Bituthene 4000 Membranes carry a Underwriters' Laboratory Class A Fire Rating (Building Materials Directory, File #R7910) when used in either of the following constructions:

—Limited to noncombustible decks at inclines not exceeding ¼ in. (6 mm) to the horizontal 1 ft (0.3 m). One layer of Bituthene waterproofing membrane, followed by one layer of ⅛ in. (3 mm) protection board, encased in 2 in. (50 mm) minimum concrete monolithic pour.

—Limited to noncombustible decks at inclines not exceeding ¼ in. (6 mm) to the horizontal 1 ft (0.3 m). One layer of Bituthene waterproofing membrane, followed by one layer of DOW Styrofoam PD Insulation Board [2 in. (50 mm) thick]. This is covered with one layer of 2 ft x 2 ft x 2 in. (0.6 m x 0.6 m x 50 mm) of concrete paver topping.

Warranty

Five year material warranties covering Bituthene and Hydroduct products are available upon request. Contact your Grace sales representative for details.

Technical Services

Support is provided by full time, technically trained Grace representatives and technical service personnel, backed by a central research and development staff.

Supply

Bituthene System 4000	3 ft x 66.7 ft roll (200 ft^2) [0.9 m x 20 m (18.6 m^2)]
Roll weight	83 lbs (38 kg) gross
Palletization	25 rolls per pallet
Storage	Store upright in dry conditions below 95°F (+35°C).
System 4000 Surface Conditioner	1 x 0.625 gal (2.3 L) bottle in each roll of System 4000 Membrane
Ancillary Products	
Surface Conditioner Sprayer	2 gal (7.6 L) capacity professional grade sprayer with specially engineered nozzle
Bituthene Liquid Membrane	1.5 gal (5.7 L) pail/125 pails per pallet or 4 gal (15.1 L) pail/48 pails per pallet
Preprufe Detail Tape	2 in. x 50 ft (50 mm x 15 m) roll/16 rolls per carton
Bituthene Mastic	Twelve 30 oz (0.9 L) tubes/carton or 5 gal (18.9 L) pail/36 pails per pallet
Complementary Material	
Hydroduct	See separate data sheets

Equipment by others: Soft broom, utility knife, brush or roller for priming

Physical Properties for Bituthene 4000 Membrane

Property	Typical Value	Test Method
Color	Dark gray-black	
Thickness	1⁄16 in. (1.5 mm) nominal	ASTM D3767—method A
Flexibility, 180° bend over 1 in. (25 mm) mandrel at -25°F (-32°C)	Unaffected	ASTM D1970
Tensile strength, membrane, die C	325 lbs/in.^{2} (2240 kPa) minimum	ASTM D412 modified[1]
Tensile strength, film	5,000 lbs/in.^{2} (34.5 MPa) minimum	ASTM D882 modified[1]
Elongation, ultimate failure of rubberized asphalt	300% minimum	ASTM D412 modified[1]
Crack cycling at -25°F (-32°C), 100 cycles	Unaffected	ASTM C836
Lap adhesion at minimum application temperature	5 lbs/in. (880 N/m)	ASTM D1876 modified[2]
Peel strength	9 lbs/in. (1576 N/m)	ASTM D903 modified[3]
Puncture resistance, membrane	50 lbs (222 N) minimum	ASTM E154
Resistance to hydrostatic head	210 ft (70 m) of water	ASTM D5385
Permeance	0.05 perms (2.9 ng/m^{2}sPa) maximum	ASTM E96, section 12—water method
Water absorption	0.1% maximum	ASTM D570

Footnotes:
1. The test is run at a rate of 2 in. (50 mm) per minute.
2. The test is conducted 15 minutes after the lap is formed and run at a rate of 2 in. (50 mm) per minute at 40°F (5°C).
3. The 180° peel strength is run at a rate of 12 in. (300 mm) per minute.

Physical Properties for System 4000 Surface Conditioner

Property	Typical Value
Solvent type	Water
Flash point	>140°F (>60°C)
VOC* content	91 g/L
Application temperature	25°F (-4°C) and above
Freeze thaw stability	5 cycles (minimum)
Freezing point (as packaged)	14°F (-10°C)
Dry time (hours)	1 hour**

* Volatile Organic Compound
** Dry time will vary with weather conditions

www.graceconstruction.com

For technical assistance call toll free at 866-333-3SBM (3726)

BIT-220H Printed in U.S.A. 10/13 FA/PDF

GRACE

Appendix J.2: Preprufe 300R Plus Tech Sheets

Grace Below Grade Waterproofing

PREPRUFE® 300R Plus & 160R Plus

Pre-applied waterproofing membranes that bond integrally to poured concrete for use below slabs or behind basement walls on confined sites

Description

Preprufe® 300R Plus & 160R Plus membranes are unique composite sheets comprising, a thick HDPE film, an aggressive pressure sensitive adhesive a weather resistant protective coating and an adhesive to adhesive seam overlap.

Unlike conventional non-adhering membranes, which are vulnerable to water ingress tracking between the unbonded membrane and structure, the unique Preprufe bond to concrete prevents ingress or migration of water around the structure.

The Preprufe R Plus System includes:

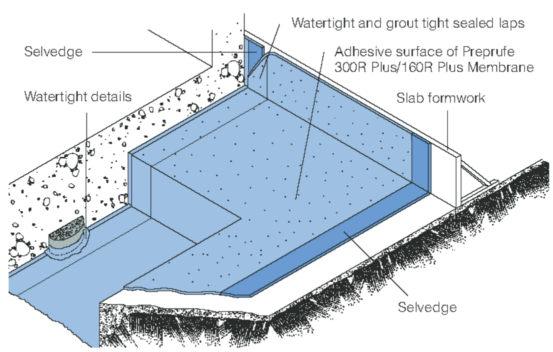
- **Preprufe 300R Plus—**heavy-duty grade for use below slabs and on rafts (i.e. mud slabs). Designed to accept the placing of heavy reinforcement using conventional concrete spacers.
- **Preprufe 160R Plus—**thinner grade for blindside, zero property line applications against soil retention systems.
- **Preprufe Tape LT—**for covering cut edges, roll ends, penetrations and detailing (temperatures between 25°F (-4°C) and 86°F (+30°C)).
- **Preprufe Tape HC—**as above for use in Hot Climates (minimum 50°F (10°C)).
- **Bituthene® Liquid Membrane—**for sealing around penetrations, etc.
- **Adcor™ ES—**waterstop for joints in concrete walls and floors
- **Preprufe Tieback Covers—**preformed cover for soil retention wall tieback heads
- **Preprufe Preformed Corners—**preformed inside and outside corners

Preprufe 300R Plus & 160R Plus membranes are applied either horizontally to smooth prepared concrete, carton forms or well rolled and compacted earth or crushed stone substrate; or vertically to permanent formwork or adjoining structures. Concrete is then cast directly against the adhesive side of the membranes. The specially developed Preprufe adhesive layers work together to form a continuous and integral seal to the structure.

Preprufe can be turned up the inside face of slab formwork but is not recommended for conventional twin-sided formwork on walls, etc. Use Bituthene® self-adhesive membrane or Procor® fluid applied membrane to walls after removal of formwork for a fully bonded system to all structural surfaces.

Advantages

- **Forms a unique continuous adhesive bond to concrete poured against it—**prevents water migration and makes it unaffected by ground settlement beneath slabs
- **Fully-adhered adhesive to adhesive watertight laps** and detailing
- **Provides a barrier to water, moisture and gas—**physically isolates the structure from the surrounding ground
- **Easy roll/kick out installation—**reduces installation time and cost
- **Release Liner free—**expedites installation and reduces construction site waste
- **Solar reflective—**reduced temperature gain
- **Simple and quick to install—**requiring no priming or fillets
- **Can be applied to permanent formwork—**allows maximum use of confined sites
- **Self protecting—**can be trafficked immediately after application and ready for immediate placing of reinforcement
- **Unaffected by wet conditions—**cannot activate prematurely
- **Inherently waterproof, non-reactive system:**
  - not reliant on confining pressures or hydration
  - unaffected by freeze/thaw, wet/dry cycling
- **Chemical resistant—**effective in most types of soils and waters, protects structure from salt or sulphate attack



Drawings are for illustration purposes only.
Please refer to graceconstruction.com for specific application details.

Installation

The most current application instructions, detail drawings and technical letters can be viewed at graceconstruction.com. For other technical information contact your local Grace representative.

Preprufe Plus has colored zip strips at the top and bottom of the seam area on the edge of the roll. Both zip strips cover an aggressive adhesive. Once the yellow zip strip on the top of the membrane and the blue zip strip on the bottom of the membrane are removed, a strong adhesive to adhesive bond is achieved in the overlap area.

Substrate Preparation

All surfaces—It is essential to create a sound and solid substrate to eliminate movement during the concrete pour. Substrates must be regular and smooth with no gaps or voids greater than 0.5 in. (12 mm). Grout around all penetrations such as utility conduits, etc. for stability (see Figure 1).

Horizontal—The substrate must be free of loose aggregate and sharp protrusions. Avoid curved or rounded substrates. When installing over earth or crushed stone, ensure substrate is well compacted to avoid displacement of substrate due to traffic or concrete pour. The surface does not need to be dry, but standing water must be removed.

Vertical—Use concrete, plywood, insulation or other approved facing to sheet piling to provide support to the membrane. Board systems such as timber lagging must be close butted to provide support and not more than 0.5 in. (12 mm) out of alignment.

Membrane Installation

Preprufe can be applied at temperatures of 25°F (-4°C) or above. When installing Preprufe in cold or marginal weather conditions <40°F (<4°C) the use of Preprufe Tape LT is recommended at all laps and detailing. Preprufe Tape LT should be applied to clean, dry surfaces and the release liner must be removed immediately after application. Alternatively, Preprufe Plus Low Temperature (LT) is available for low temperature condition applications. Refer to Preprufe Plus LT data sheet for more information.

Horizontal substrates—Kick out or roll out the membrane HDPE film side to the substrate with the yellow zip strip facing towards the concrete pour. End laps should be staggered to avoid a build up of layers. Leave yellow and blue zip strips on the membrane until overlap procedure is completed.

Accurately position succeeding sheets to overlap the previous sheet 3 in. (75 mm) along the marked selvedge with the blue zip strip on top of the yellow zip strip. Ensure the underside of the succeeding sheet is clean, dry and free from contamination before attempting to overlap. Peel back and remove both the yellow and blue zip strips in the overlap area to achieve an adhesive to adhesive bond at the overlap. Ensure a continuous bond is achieved without creases and roll firmly with a heavy roller.

Refer to Grace Tech Letter 15 for information on suitable rebar chairs for Preprufe.

Vertical substrates—Mechanically fasten the membrane vertically using fasteners appropriate to the substrate with the yellow zip strip facing towards the concrete pour. The membrane may be installed in any convenient length. Fastening can be made through the selvedge using a small and low profile head fastener so that the membrane lays flat and allows firmly rolled overlaps. Accurately position succeeding sheets to overlap the previous sheet 3 in. (75 mm) along the marked selvedge with the blue zip strip on top of the yellow zip strip. Ensure the underside of the succeeding sheet is clean, dry and free from contamination before attempting to overlap. Peel back and remove both the yellow and blue zip strips in the overlap area to achieve an adhesive to adhesive bond at the overlap. Roll firmly to ensure a watertight seal.

Roll ends and cut edges—Overlap all roll ends and cut edges by a minimum 3 in. (75 mm) and ensure the area is clean and free from contamination, wiping with a damp cloth if necessary. Allow to dry and apply Preprufe Tape LT (or HC in hot climates) centered over the lap edges and roll firmly (see Figure 2). Immediately remove tinted plastic release liner from the tape.

Details

Refer to Preprufe Field Application Manual, Section V Application Instructions or visit graceconstruction.com. This manual gives comprehensive guidance and standard details.

Membrane Repair

Inspect the membrane before installation of reinforcement steel, formwork and final placement of concrete. The membrane can be easily cleaned by power washing if required. Repair damage by wiping the area with a damp cloth to ensure the area is clean and free from dust, and allow to dry. Repair small punctures (0.5 in. (12 mm) or less) and slices by applying Preprufe Tape centered over the damaged area and roll firmly. Remove the release liner from the tape. Repair holes and large punctures by applying a patch of Preprufe membrane, which extends 6 in. (150 mm) beyond the damaged area. Seal all edges of the patch with Preprufe Tape, remove the release liner from the tape and roll firmly. Any areas of damaged adhesive should be covered with Preprufe Tape. Remove tinted plastic release liner from tape. Where exposed selvedge has lost adhesion or laps have not been sealed, ensure the area is clean and dry and cover with fresh Preprufe Tape, rolling firmly. Alternatively, use a hot air gun or similar to activate adhesive and firmly roll lap to achieve continuity.

Pouring of Concrete

Ensure the plastic release liner is removed from all areas of Preprufe Tape.

It is recommended that concrete be poured within 56 days (42 days in hot climates) of application of the membrane. Following proper ACI guidelines, concrete must be placed carefully and consolidated properly to avoid damage to the membrane. Never use a sharp object to consolidate the concrete. Provide temporary protection from concrete over splash for areas of the Preprufe membrane that are adjacent to a concrete pour.

Removal of Formwork

Preprufe membranes can be applied to removable formwork, such as slab perimeters, elevator and lift pits, etc. Once the concrete is poured the formwork must remain in place until the concrete has gained sufficient compressive strength to develop the surface bond. Preprufe membranes are not recommended for conventional twin-sided wall forming systems.

A minimum concrete compressive strength of 1500 psi (10 N/mm²) is recommended prior to stripping formwork supporting Preprufe membranes. Premature stripping may result in displacement of the membrane and/or spalling of the concrete.

Refer to Grace Tech Letter 17 for information on removal of formwork for Preprufe.

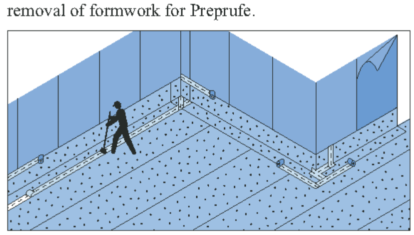


Figure 1

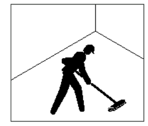
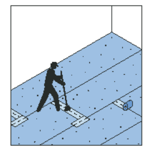


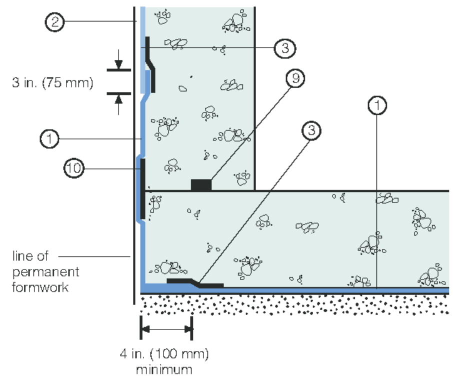
Figure 2



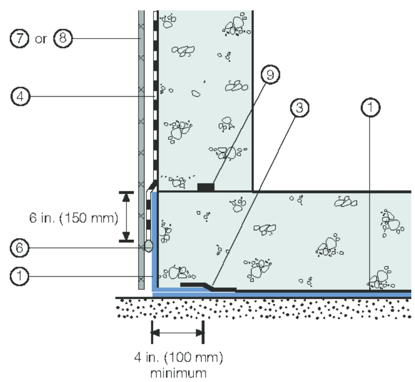
Detail Drawings

Details shown are typical illustrations and not working details. For a list of the most current details, visit us at graceconstruction.com. For technical assistance with detailing and problem solving please call toll free at 866-333-3SBM (3726).

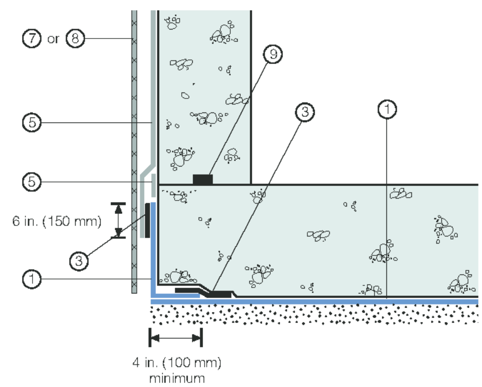
Wall base detail against permanent shutter



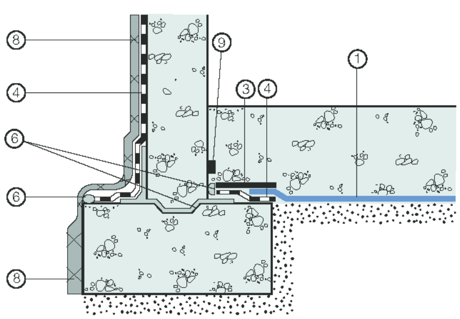
Bituthene wall base detail (Option 1)



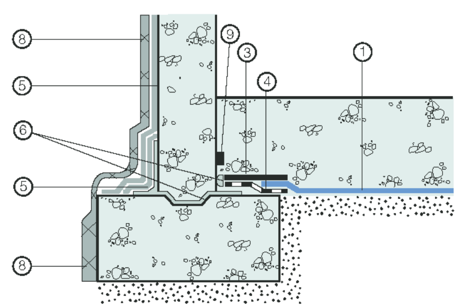
Procor wall base detail (Option 1)



Bituthene wall base detail (Option 2)



Procor wall base detail (Option 2)



1 **Preprufe 300R Plus**
2 **Preprufe 160R Plus**
3 **Preprufe Tape**
4 **Bituthene®**
5 **Procor**
6 **Bituthene Liquid Membrane**
7 **Protection**
8 **Hydroduct®**
9 **Adcor ES**
10 **Preprufe CJ Tape**

Supply

Dimensions (Nominal)	Preprufe 300R Plus Membrane	Preprufe 160R Plus Membrane	Preprufe Tape (LT or HC*)
Thickness	0.046 in. (1.2 mm)	0.032 in. (0.8 mm)	
Roll size	3 ft. 10 in. x 102 ft. (1.17m x 31.15m)	3 ft. 10 in. x 120 ft. (1.17m x 36.6m)	4 in. x 49 ft (100 mm x 15 m)
Roll area	392 ft² (36 m²)	460 ft² (42 m²)	
Roll weight	108 lbs (50 kg)	92 lbs (42 kg)	4.3 lbs (2 kg)
Minimum side/end laps	3 in. (75 mm)	3 in. (75 mm)	3 in. (75 mm)
* LT denotes Low Temperature (between 25°F (-4°C) and 86°F (+30°C)) HC denotes Hot Climate (50°F (>+10°C))			
Ancillary Products			
Bituthene Liquid Membrane—1.5 US gal (5.7 liter) or 4 US gal (15.1 liter)			

Physical Properties

Property	Typical Value 300R Plus	Typical Value 160R Plus	Test Method
Color	white	white	
Thickness	0.046 in. (1.2 mm)	0.032 in. (0.8 mm)	ASTM D3767
Lateral Water Migration Resistance	Pass at 231 ft (71 m) of hydrostatic head pressure	Pass at 231 ft (71 m) of hydrostatic head pressure	ASTM D5385, modified[1]
Low temperature flexibility	Unaffected at -20°F (-29°C)	Unaffected at -20°F (-29°C)	ASTM D1970
Resistance to hydrostatic head	231 ft (71 m)	231 ft (71 m)	ASTM D5385, modified[2]
Elongation	500%	500%	ASTM D412, modified[3]
Tensile strength, film	4000 psi (27.6 MPa)	4000 psi (27.6 MPa)	ASTM D412
Crack cycling at -9.4°F (-23°C), 100 cycles	Unaffected, Pass	Unaffected, Pass	ASTM C836[4]
Puncture resistance	221 lbs (990 N)	100 lbs (445 N)	ASTM E154
Peel adhesion to concrete	5 lbs/in. (880 N/m)	5 lbs/in. (880 N/m)	ASTM D903, modified[5]
Lap peel adhesion at 72°F (22°C)	8 lbs/in. (1408 N/m)	8 lbs/in. (1408 N/m)	ASTM D1876, modified[6]
Lap peel adhesion at 40°F (4°C)	8 lbs/in. (1408 N/m)	8 lbs/in. (1408 N/m)	ASTM D1876, modified[6]
Permeance to water vapor transmission	0.01 perms (0.6 ng/(Pa x s x m²))	0.01 perms (0.6 ng/(Pa x s x m²))	ASTM E96, method B

Footnotes:
1. Lateral water migration resistance is tested by casting concrete against membrane with a hole and subjecting the membrane to hydrostatic head pressure with water. The test measures the resistance of lateral water migration between the concrete and the membrane.
2. Hydrostatic head tests of Preprufe Membranes are performed by casting concrete against the membrane with a lap. Before the concrete cures, a 0.125 in. (3 mm) spacer is inserted perpendicular to the membrane to create a gap. The cured block is placed in a chamber where water is introduced to the membrane surface up to the head indicated.
3. Elongation of membrane is run at a rate of 2 in. (50 mm) per minute.
4. Concrete is cast against the Preprufe membrane and allowed to cure (7 days minimum)
5. Concrete is cast against the protective coating surface of the membrane and allowed to properly dry (7 days minimum). Peel adhesion of membrane to concrete is measured at a rate of 2 in. (50 mm) per minute at room temperature.
6. The test is conducted 15 minutes after the lap is formed (per Grace published recommendations) and run at a rate of 2 in. (50 mm) per minute at 72°F (22°C).

Specification Clauses

Preprufe 300R Plus or 160R Plus shall be applied with its adhesive face presented to receive fresh concrete to which it will integrally bond. Only Grace Construction Products approved membranes shall be bonded to Preprufe. All Preprufe system materials shall be supplied by Grace Construction Products, and applied strictly in accordance with their instructions. Specimen performance and formatted clauses are also available.

NOTE: Use Preprufe Tape to tie-in Procor with Preprufe.

Health and Safety

Refer to relevant Material Safety data sheet. Complete rolls should be lifted and carried by a minimum of two persons.

www.graceconstruction.com

For technical assistance call toll free at 866-333-3SBM (3726)

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GRACE

Appendix J.3: Boring Locations

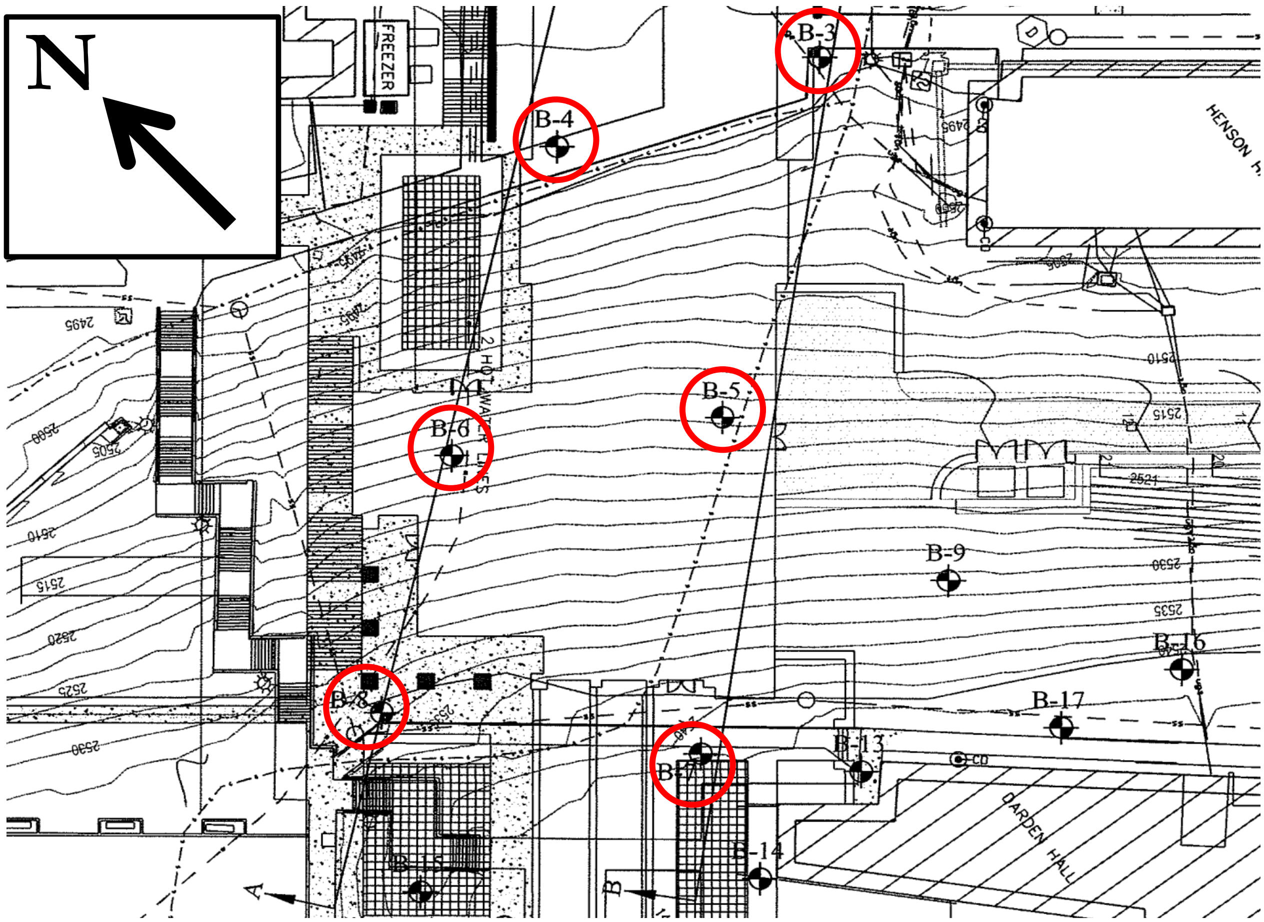

Figure J1: Test Boring Locations (From Geotechnical Report)

Appendix J.4: Allowable Piping Materials for Subsoil Drain Pipes

TABLE 1102.5 SUBSOIL DRAIN PIPE

MATERIAL	STANDARD
Asbestos-cement pipe	ASTM C 508
Cast-iron pipe	ASTM A 74; ASTM A 888; CISPI 301
Polyethylene (PE) plastic pipe	ASTM F 405; CSA B182.1; CSA B182.6; CSA B182.8
Polyvinyl chloride (PVC) Plastic pipe (type sewer pipe, PS25, PS50 or PS100)	ASTM D 2729; ASTM F 891; CSA B182.2; CSA B182.4
Stainless steel drainage systems, Type 316L	ASME A 112.3.1
Vitrified clay pipe	ASTM C 4; ASTM C 700

Figure J2: IPC2012 Table 1102.5

Appendix J.5: PVC Pipe Nomograph

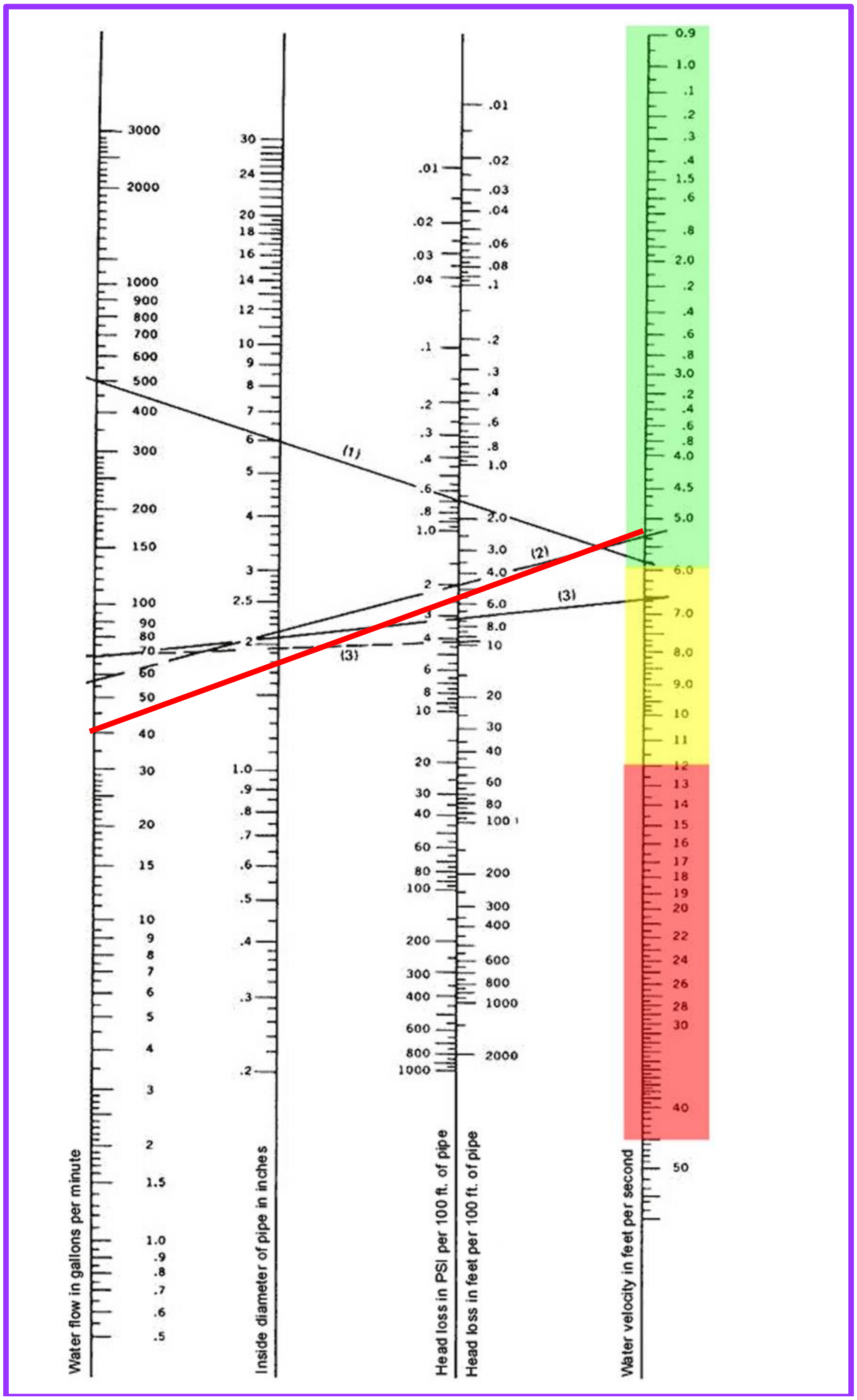

Figure J3: PVC Pipe Nomograph

Appendix K: Detailed Cost Estimate

Formwork - Exterior Beams - 03 11 13. 20 (1500)							
Level	Dim.	L. F.	S.F.C.A.	Material	Labor	Equipment	Total
				1.02	6.15	0	7.17
Lower Roof	24" x 30"	72	468	477.36	2878.20	0.00	3355.56
	24" x 24"	222.5	1335	1361.70	8210.25	0.00	9571.95
6	24" x 30"	72	468	-	2878.20	0.00	2878.20
	24" x 24"	178.2	1069	-	6575.58	0.00	6575.58
5	24" x 30"	72	468	-	2878.20	0.00	2878.20
	24" x 24"	178.2	1069	-	6575.58	0.00	6575.58
4	24" x 30"	95.3	619	631.84	3809.62	0.00	4441.46
	24" x 24"	201.5	1209	1233.18	7435.35	0.00	8668.53
3	24" x 30"	95.3	619	-	3809.62	0.00	3809.62
	24" x 24"	151.9	911	-	5605.11	0.00	5605.11
2	24" x 30"	95.3	619	-	3809.62	0.00	3809.62
	24" x 24"	97.6	586	-	3601.44	0.00	3601.44
Total			**9442**	**$ 3,704**	**$ 58,067**	**$ -**	**$ 61,771**

Formwork - Interior Beams - 03 11 13. 20 (2500)							
Dim.	Level	L. F.	S.F.C.A.	Material	Labor	Equipment	Total
				2.57	6.05	0	8.62
24" x 30"	Lower Roof	50	324	831.91	1958.39	0.00	2790.29
	6	50	324	831.91	1958.39	0.00	2790.29
	5	50	324	-	1958.39	0.00	1958.39
	4	50	324	-	1958.39	0.00	1958.39
	3	50	324	-	1958.39	0.00	1958.39
	2	50	324	-	1958.39	0.00	1958.39
Dim.	Level	L. F.	S.F.C.A.	Material	Labor	Equipment	Total
				1.41	5.25	0	6.66
16" x 24"	Lower Roof	78.2	365	-	1915.90	0.00	1915.90
	6	78.2	365	514.56	1915.90	0.00	2430.46
	5	78.2	417	588.06	2189.60	0.00	2777.66
	4	78.2	365	-	1915.90	0.00	1915.90
	3	78.2	365	-	1915.90	0.00	1915.90
	2	62.7	293	-	1536.15	0.00	1536.15

Formwork - Interior Beams - 03 11 13. 20 (2000)							
Dim.	Level	L. F.	S.F.C.A.	Material	Labor	Equipment	Total
				1.71	5.4	0	7.11
10" x 12"	Lower Roof	16.7	45	76.15	240.48	0.00	316.63
	6	16.7	45	76.15	240.48	0.00	316.63
	5	16.7	45	-	240.48	0.00	240.48
	4	16.7	45	-	240.48	0.00	240.48
	3	16.7	45	-	240.48	0.00	240.48
	2	16.7	45	-	240.48	0.00	240.48
Total			**4379**	**$ 2,919**	**$ 24,583**	**$ -**	**$ 27,502**

Formwork - Columns - 03 11 13. 25 (6500)								
Level	Dim.	Height	Number	S.F.C.A.	Material	Labor	Equipment	Total
					0.74	5.3	0	6.04
6	24" x 24"	18	18	2592	-	13737.60	0.00	13737.60
5	24" x 24"	16	18	2304	-	12211.20	0.00	12211.20
4	24" x 24"	16	17	2176	-	11532.80	0.00	11532.80
3	24" x 24"	16	20	2560	1894.40	13568.00	0.00	15462.40
2	24" x 24"	18	13	1872	-	9921.60	0.00	9921.60
1	24" x 24"	18	6	864	-	4579.20	0.00	4579.20
Total				**12368**	**$ 1,895**	**$ 65,551**	**$ -**	**$ 67,445**

Formwork - Elevated Slabs - 03 11 13. 35 (2250)					
Level	S.F.	Material	Labor	Equipment	Total
		5	4.05	0	9.05
Lower Roof	10738	-	43486.88	0.00	43486.88
6	8885	-	35984.25	0.00	35984.25
5	8885	-	35984.25	0.00	35984.25
4	11448	-	46364.40	0.00	46364.40
3	11448	57240.00	46364.40	0.00	103604.40
2	8967	44835.00	36316.35	0.00	81151.35
Total	**60371**	**$ 102,075**	**$ 244,501**	**$ -**	**$ 346,576**

Formwork Total (+10% Waste)
$ 553,622

Structural Concrete - Exterior Beams - 03 31 05.35 (0300)							
Level	Dim.	L. F.	CY	Material	Labor	Equipment	Total
				103	0	0	103
Lower Roof	24" x 30"	72	8.9	915.56	0	0	915.56
	24" x 24"	222.5	19.2	1980.52	0	0	1980.52
6	24" x 30"	72	8.9	915.56	0	0	915.56
	24" x 24"	178.2	15.4	1586.20	0	0	1586.20
5	24" x 30"	72	8.9	915.56	0	0	915.56
	24" x 24"	178.2	15.4	1586.20	0	0	1586.20
4	24" x 30"	95.3	11.8	1211.84	0	0	1211.84
	24" x 24"	201.5	17.4	1793.60	0	0	1793.60
3	24" x 30"	95.3	11.8	1211.84	0	0	1211.84
	24" x 24"	151.9	13.1	1352.10	0	0	1352.10
2	24" x 30"	95.3	11.8	1211.84	0	0	1211.84
	24" x 24"	97.6	8.4	868.76	0	0	868.76
Total			**151**	**$ 15,550**	**$ -**	**$ -**	**$ 15,550**

Structural Concrete - Interior Beams -03 31 05.35 (0300)							
Dim.	Level	L. F.	CY	Material	Labor	Equipment	Total
				103	0	0	103
24" x 30"	Lower Roof	50	6.1	633.26	0	0	633.26
	6	50	6.1	633.26	0	0	633.26
	5	50	6.1	633.26	0	0	633.26
	4	50	6.1	633.26	0	0	633.26
	3	50	6.1	633.26	0	0	633.26
	2	50	6.1	633.26	0	0	633.26
Dim.	Level	L. F.	CY	Material	Labor	Equipment	Total
				103	0	0	103
16" x 24"	Lower Roof	78.2	4.5	464.05	0	0	464.05
	6	78.2	4.5	464.05	0	0	464.05
	5	78.2	4.5	464.05	0	0	464.05
	4	78.2	4.5	464.05	0	0	464.05
	3	78.2	4.5	464.05	0	0	464.05
	2	62.7	3.6	372.07	0	0	372.07

Dim.	Level	L. F.	CY	Material	Labor	Equipment	Total
				103	0	0	103
10" x 12"	Lower Roof	16.7	0.09	8.85	0	0	8.85
	6	16.7	0.09	8.85	0	0	8.85
	5	16.7	0.09	8.85	0	0	8.85
	4	16.7	0.09	8.85	0	0	8.85
	3	16.7	0.09	8.85	0	0	8.85
	2	16.7	0.09	8.85	0	0	8.85
Total			**64**	**$ 6,545**	**$ -**	**$ -**	**$ 6,545**

Structural Concrete - Columns - 03 31 05.35 (0300)								
Level	Dim.	Height	Number	CY	Material	Labor	Equipment	Total
					103	0	0	103
6	24" x 24"	18	18	48	4944.00	0	0	4944.00
5	24" x 24"	16	18	43	4394.67	0	0	4394.67
4	24" x 24"	16	17	40	4150.52	0	0	4150.52
3	24" x 24"	16	20	47	4882.96	0	0	4882.96
2	24" x 24"	18	13	35	3570.67	0	0	3570.67
1	24" x 24"	18	6	16	1648.00	0	0	1648.00
Total				**229**	**$ 23,591**	**$ -**	**$ -**	**$ 23,591**

Structural Concrete - Slab and Drop Cap - 03 31 05.35 (0300)											
Level	Slab S.F.	Slab Thick. (ft)	Drop Panel S.F.	Drop Panel Thick. (ft)	Shallow Beam S.F.	Shallow Beam Thick.	CY	Material	Labor	Equip.	Total
								111	0	0	111
Lower Roof	10738	0.83	49	0.5	355.6	0.33	336.70	37373.91	0	0	37373.91
6	8885	0.83	49	0.5	355.6	0.33	279.53	31027.38	0	0	31027.38
5	8885	0.83	49	0.5	355.6	0.33	279.53	31027.38	0	0	31027.38
4	11448	0.83	49	0.5	355.6	0.33	358.63	39808.03	0	0	39808.03
3	11448	0.83	49	0.5	355.6	0.33	358.63	39808.03	0	0	39808.03
2	8967	0.83	49	0.5	355.6	0.33	282.06	31308.30	0	0	31308.30
Total							**1895.07**	**$ 210,354**	**$ -**	**$ -**	**$ 210,354**

Structural Concrete Total (+7% Waste)
$ 273,962

Finishing - Slabs - 03 31 29.30 (0200)					
Level	Slab S.F.	Material	Labor	Equipment	Total
		0	0.71	0	0.71
Lower Roof	10738	0	7624	0	7623.6
6	8885	0	6308	0	6308.4
5	8885	0	6308	0	6308.4
4	11448	0	8128	0	8128.1
3	11448	0	8128	0	8128.1
2	8967	0	6367	0	6366.6
Total	**60370.5**	**$ -**	**$ 42,864**	**$ -**	**$ 42,864**

Placing Concrete - Exterior Beams - 03 31 05.70 (0200)							
Level	Dim.	L. F.	CY	Material	Labor	Equipment	Total
				0	25	8.9	33.9
Lower Roof	24" x 30"	72	9	0	222.22	79.11	301.33
	24" x 24"	222.5	19	0	480.71	171.13	651.84
6	24" x 30"	72	9	0	222.22	79.11	301.33
	24" x 24"	178.2	15	0	385.00	137.06	522.06
5	24" x 30"	72	9	0	222.22	79.11	301.33
	24" x 24"	178.2	15	0	385.00	137.06	522.06
4	24" x 30"	95.3	12	0	294.14	104.71	398.85
	24" x 24"	201.5	17	0	435.34	154.98	590.32
3	24" x 30"	95.3	12	0	294.14	104.71	398.85
	24" x 24"	151.9	13	0	328.18	116.83	445.01
2	24" x 30"	95.3	12	0	294.14	104.71	398.85
	24" x 24"	97.6	8	0	210.86	75.07	285.93
Total			**151**	**$ -**	**$ 3,775**	**$ 1,344**	**$ 5,118**

Placing Concrete - Interior Beams -03 31 05.70 (0200)							
Dim.	Level	L. F.	CY	Material	Labor	Equipment	Total
				0	25	8.9	33.9
24" x 30"	Lower Roof	49.8	6	0	153.70	54.72	208.42
	6	49.8	6	0	153.70	54.72	208.42
	5	49.8	6	0	153.70	54.72	208.42
	4	49.8	6	0	153.70	54.72	208.42
	3	49.8	6	0	153.70	54.72	208.42
	2	49.8	6	0	153.70	54.72	208.42

Dim.	Level	L. F.	CY	Material	Labor	Equipment	Total
				0	25	8.9	33.9
16" x 24"	Lower Roof	78.2	5	0	112.63	40.10	152.73
	6	78.2	5	0	112.63	40.10	152.73
	5	78.2	5	0	112.63	40.10	152.73
	4	78.2	5	0	112.63	40.10	152.73
	3	78.2	5	0	112.63	40.10	152.73
	2	62.7	4	0	90.31	32.15	122.46

Placing Concrete - Interior Beams -03 31 05.70 (0050)							
Dim.	Level	L. F.	CY	Material	Labor	Equipment	Total
				0	38	13.3	51.3
10" x 12"	Lower Roof	16.7	0	0	3.26	1.14	2.91
	6	16.7	0	0	3.26	1.14	2.91
	5	16.7	0	0	3.26	1.14	2.91
	4	16.7	0	0	3.26	1.14	2.91
	3	16.7	0	0	3.26	1.14	2.91
	2	16.7	0	0	3.26	1.14	2.91
Total			**64**	**$ -**	**$ 1,596**	**$ 568**	**$ 2,154**

Placing Concrete - Columns - 03 31 05.70 (0800)								
Level	Dim.	Height	Number	CY	Material	Labor	Equipment	Total
					0	24.5	8.7	
6	24" x 24"	18	18.00	48.00	0	1176.00	417.60	1593.60
5	24" x 24"	16	18.00	42.67	0	1045.33	371.20	1416.53
4	24" x 24"	16	17.00	40.30	0	987.26	350.58	1337.84
3	24" x 24"	16	20.00	47.41	0	1161.48	412.44	1573.93
2	24" x 24"	18	13.00	34.67	0	849.33	301.60	1150.93
1	24" x 24"	18	6.00	16.00	0	392.00	139.20	531.20
Total				**230**	**$ -**	**$ 5,612**	**$ 1,993**	**$ 7,605**

Placing Concrete - Slab and Drop Panel - 03 31 05.70 (1500)											
Level	Slab S.F.	Slab Thick. (ft)	Drop Panel S.F.	Drop Panel Thick. (ft)	Shallow Beam S.F.	Shallow Beam Thick.	CY	Material	Labor	Equip.	Total
								0	14.15	5	19.15
Lower Roof	10738	0.83	49	0.5	355.6	0.33	336.70	0	4764.33	1683.51	6447.84
6	8885	0.83	49	0.5	355.6	0.33	279.53	0	3955.29	1397.63	5352.92
5	8885	0.83	49	0.5	355.6	0.33	279.53	0	3955.29	1397.63	5352.92
4	11448	0.83	49	0.5	355.6	0.33	358.63	0	5074.63	1793.15	6867.78
3	11448	0.83	49	0.5	355.6	0.33	358.63	0	5074.63	1793.15	6867.78
2	8967	0.83	49	0.5	355.6	0.33	282.06	0	3991.10	1410.28	5401.39
Total							**1896**	**$ -**	**$ 26,816**	**$ 9,476**	**$ 36,291**

Placing Concrete Total
$ 51,167

Reinforcement Bars - Beams - 03 21 10. 60 (0100)					
Level	Tons	Material	Labor	Equipment	Total
		800	935	0	1735
Lower Roof	10.2	8136	9509.4	0	17645.8
6	10.2	8136	9509.4	0	17645.8
5	10.0	7976	9322.4	0	17298.8
4	9	7576	8854.9	0	16431.3
3	9	7576	8854.9	0	16431.3
2	9	7576	8854.9	0	16431.3
Total		**46,979**	**$ 54,906**	**-**	**$ 101,885**

Reinforcement Bars - Columns - 03 21 10. 60 (0250)							
Level	Height	Number	Tons	Material	Labor	Equipment	Total
				800	650	0	1450
Lower Roof	18	18	3	2768.26	2249.21	0	5017.5
6	16	18	3	2460.67	1999.30	0	4460.0
5	16	17	3	2323.97	1888.22	0	4212.2
4	16	20	3	2734.08	2221.44	0	4955.5
3	18	13	2	1999.30	1624.43	0	3623.7
2	18	6	1	922.75	749.74	0	1672.5
Total			**16.5**	**$ 13,210**	**$ 10,733**	**-**	**$ 23,942**

Reinforcement Bars - Slabs - 03 21 10. 60 (0400)					
Level	Tons	Material	Labor	Equipment	Total
		850	515	0	1365
Lower Roof	12.3	10480.5	6350.0	0	16830.5
6	10.2	8631.0	5229.4	0	13860.4
5	10.2	8631.0	5229.4	0	13860.4
4	13.1	11169.0	6767.1	0	17936.1
3	13.1	11169.0	6767.1	0	17936.1
2	10.2	8631.0	5229.4	0	13860.4
Total		**$ 58,712**	**$ 35,573**	**-**	**$ 94,284**

Reinforcement Total (+10% Waste)
$ 231,115

Adjustment Factors

Time: Assuming an Inflation Rate of 3%

$$\frac{BCI\ 2014}{BCI\ 2010} = 1.09$$

$$[1 + (0.25 * 0.03)] = 1.0075$$

Multiplier = 1.09 * 1.0075 = 1.1

Location: No location multiplier used. Recommended multiplier would be 0.79 for Bristol, VA. This is not accurate due to the building being located on a University Campus.

Appendix L: Schedule Durations

Formwork - Exterior Beams - 03 11 13. 20 (1500)					
Level	Dim.	L. F.	S.F.C.A.	Daily Output	Durations
Lower Roof	24" x 30"	72	468	795	0.59
	24" x 24"	222.5	1335	795	1.68
6	24" x 30"	72	468	795	0.59
	24" x 24"	178.2	1069	795	1.34
5	24" x 30"	72	468	795	0.59
	24" x 24"	178.2	1069	795	1.34
4	24" x 30"	95.3	619	795	0.78
	24" x 24"	201.5	1209	795	1.52
3	24" x 30"	95.3	619	795	0.78
	24" x 24"	151.9	911	795	1.15
2	24" x 30"	95.3	619	795	0.78
	24" x 24"	97.6	586	795	0.74
Total			**9442**	**9540**	**12**

Formwork - Interior Beams - 03 11 13. 20 (2500)					
Dim.	Level	L. F.	S.F.C.A.	Daily Output	Durations
24" x 30"	Lower Roof	50	324	960	0.34
	6	50	324	960	0.34
	5	50	324	960	0.34
	4	50	324	960	0.34
	3	50	324	960	0.34
	2	50	324	960	0.34
Dim.	Level	L. F.	S.F.C.A.	Daily Output	Durations
16" x 24"	Lower Roof	78.2	365	921	0.40
	6	78.2	365	921	0.40
	5	78.2	417	921	0.45
	4	78.2	365	921	0.40
	3	78.2	365	921	0.40
	2	62.7	293	921	0.32

Formwork - Interior Beams - 03 11 13. 20 (2000)					
Dim.	Level	L. F.	S.F.C.A.	Daily Output	Durations
10" x 12"	Lower Roof	16.7	45	900	0.05
	6	16.7	45	900	0.05
	5	16.7	45	900	0.05
	4	16.7	45	900	0.05
	3	16.7	45	900	0.05
	2	16.7	45	900	0.05
Total			**4379**	**16686**	**5**

Formwork - Columns - 03 11 13. 25 (6500)							
Level	Dim.	Height	Number	S.F.C.A.	Daily Output	Calculated Durations	Actual Durations
6	24" x 24"	18	380	2.27	380	2.27	1
5	24" x 24"	16	380	4.93	380	4.93	2
4	24" x 24"	16	380	6.74	380	6.74	2
3	24" x 24"	16	380	5.73	380	5.73	2
2	24" x 24"	18	380	6.06	380	6.06	2
1	24" x 24"	18	380	6.82	380	6.82	2
Total				**12368**	**32280**	**33**	**11**

Formwork - Elevated Slabs - 03 11 13. 35 (2250)			
Level	S.F.	Daily Output	Durations
Lower Roof	10738	1440	6.23
6	8885	1440	7.95
5	8885	1440	7.95
4	11448	1440	6.17
3	11448	1440	6.17
2	8967	1440	7.46
Total	**60371**	**8640**	**78**

Finishing - Slabs - 03 31 29.30 (0200)			
Level	Slab S.F.	Daily Output	Durations
Lower Roof	10738	2530	4.2
6	8885	2530	3.5
5	8885	2530	3.5
4	11448	2530	4.5
3	11448	2530	4.5
2	8967	2530	3.5
Total	**60371**	**5180**	**24**

Placing Concrete - Exterior Beams - 03 31 05.70 (0200)					
Level	Dim.	L. F.	CY	Daily Output	Durations
Lower Roof	24" x 30"	72	9	90	0.10
	24" x 24"	222.5	19	90	0.21
6	24" x 30"	72	9	90	0.10
	24" x 24"	178.2	15	90	0.17
5	24" x 30"	72	9	90	0.10
	24" x 24"	178.2	15	90	0.17
4	24" x 30"	95.3	12	90	0.13
	24" x 24"	201.5	17	90	0.19
3	24" x 30"	95.3	12	90	0.13
	24" x 24"	151.9	13	90	0.15
2	24" x 30"	95.3	12	90	0.13
	24" x 24"	97.6	8	90	0.09
Total			**151**	**1080**	**2**

Placing Concrete - Interior Beams -03 31 05.70 (0200)					
Dim.	Level	L. F.	CY	Daily Output	Durations
24" x 30"	Lower Roof	49.8	6	90	0.07
	6	49.8	6	90	0.07
	5	49.8	6	90	0.07
	4	49.8	6	90	0.07
	3	49.8	6	90	0.07
	2	49.8	6	90	0.07
Dim.	Level	L. F.	CY	Daily Output	Durations
16" x 24"	Lower Roof	78.2	5	90	0.05
	6	78.2	5	90	0.05
	5	78.2	5	90	0.05
	4	78.2	5	90	0.05
	3	78.2	5	90	0.05
	2	62.7	4	90	0.04

Placing Concrete - Interior Beams -03 31 05.70 (0050)					
Dim.	Level	L. F.	CY	Daily Output	Durations
10" x 12"	Lower Roof	16.7	0	60	0.001
	6	16.7	0	60	0.001
	5	16.7	0	60	0.001
	4	16.7	0	60	0.001
	3	16.7	0	60	0.001
	2	16.7	0	60	0.001
Total			**64**	**1440**	**1**

Placing Concrete - Columns - 03 31 05.70 (0800)						
Level	Dim.	Height	Number	CY	Daily Output	Durations
6	24" x 24"	18	18.00	48.00	92	0.17
5	24" x 24"	16	18.00	42.67	92	0.38
4	24" x 24"	16	17.00	40.30	92	0.52
3	24" x 24"	16	20.00	47.41	92	0.44
2	24" x 24"	18	13.00	34.67	92	0.46
1	24" x 24"	18	6.00	16.00	92	0.52
Total				**229**	**552**	**3**

Placing Concrete - Slab and Drop Panel - 03 31 05.70 (1500)									
Level	Slab S.F.	Slab Thick. (ft)	Drop Panel S.F.	Drop Panel Thick. (ft)	Shallow Beam S.F.	Shallow Beam Thick.	CY	Daily Output	Durations
Lower Roof	10738	0.83	49	0.5	355.6	0.33	336.70	160	2.10
6	8885	0.83	49	0.5	355.6	0.33	279.53	160	1.75
5	8885	0.83	49	0.5	355.6	0.33	279.53	160	1.75
4	11448	0.83	49	0.5	355.6	0.33	358.63	160	2.24
3	11448	0.83	49	0.5	355.6	0.33	358.63	160	2.24
2	8967	0.83	49	0.5	355.6	0.33	282.06	160	1.76
Total							**1895**	**960**	**12**

Reinforcement Bars - Beams - 03 21 10. 60 (0100)			
Level	Tons	Daily Output	Durations
Lower Roof	10.2	1.6	6.4
6	10.2	1.6	6.4
5	10.0	1.6	6.2
4	9	1.6	5.9
3	9	1.6	5.9
2	9	1.6	5.9
Total		**9.6**	**3.7**

Reinforcement Bars - Columns - 03 21 10. 60 (0250)					
Level	Height	Number	Tons	Daily Output	Durations
Lower Roof	18	18	3	2.3	0.5
6	16	18	3	2.3	1.1
5	16	17	3	2.3	1.5
4	16	20	3	2.3	1.3
3	18	13	2	2.3	1.3
2	18	6	1	2.3	1.5
Total			**16.5**	**13.8**	**8**

Reinforcement Bars - Slabs - 03 21 10. 60 (0400)			
Level	Tons	Daily Output	Durations
Lower Roof	12.3	2.9	3.5
6	10.2	2.9	4.5
5	10.2	2.9	4.5
4	13.1	2.9	3.5
3	13.1	2.9	3.5
2	10.2	2.9	4.3
Total		**17.4**	**24**